Progress in the Mechanization of Strawberry Harvesting

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C O N T E N T S

INTRODUCTION 1

EQUIPMENT CONSTRUCTED AND TESTED IN 1969 2

Floating Shoe 2

Mowing Unit 2

Picking Reels - Model III 4

Chain-Bar Unit 7

QUALITY STUDIES ON MECHANICALLY HARVESTED STRAWBERRIES 8

Composition of Mechanically Harvested Strawberry Lots 9

Quality Assessment of Processed Product 12

PROGRESS IN THE MECHANIZATION OF STRAWBERRY HARVESTING

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INTRODUCTION

Harvesting has a greater labor requirement than any other phase of strawberry production. It is also the most costly operation confronting growers. In an attempt to reduce the harvest labor requirement, research efforts have been directed toward developing a field harvester. Results of the research are summarized in this publication.

In 1967 an experimental half-row, pull-type harvester was field tested. Detachment of the fruit was accomplished by the stripping action of curved steel fingers combing through the plants. The fingers were attached to bars that were arranged to form a hollow cylinder or picking reel. Since the Northwest strawberry fruit grows close to the ground, the picking reel was oriented so that the fingers approached the plants from the side of the row, thereby minimizing contact with the plant crown. The fingers were 0.25 inch in diameter and there was an 0.625 inch space between fingers.

A harvester having two picking reels was field tested in 1968. This one-row machine was self-propelled and had cleaning and conveying systems to handle the harvested fruit. The picking reel fingers were 0.375 inch in diameter and there was an 0.75 inch space between fingers. Unfortunately, these changes along with several modifications in picking reel construction did not result in improved harvesting characteristics. The intent of the test was to investigate the effectiveness of different diameter fingers and the selective harvesting potential of the fingers at various spacings. Available field time did not permit the testing of other picking fingers in 1968.

The 1968 harvester frame was designed to serve as a carrier for testing picking devices other than the picking reels originally installed. Information gained from the 1968 operation suggested several modifications in the unit which would enhance its operation in future field tests.

Steering, speed, and direction control linkages were modified. Changes were made in the final drive of the harvester. The hydrostatic transmission received a complete factory overhaul. A larger lawn mower was installed on the front of the harvester to facilitate topping of the strawberry plants. The pneumatic cleaning system was rebuilt and a larger engine was installed to drive the fan. Changes were made in the harvester's hydraulic system to accommodate the 1969 picking devices. And finally, the subframe on which the picking devices were to be mounted was modified to permit a relatively quick and easy changeover from one picking device to another.

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EQUIPMENT CONSTRUCTED AND TESTED IN 1969

Four picking devices were investigated in 1969. Each of the units was mounted on the 1968 harvester frame for field test purposes. The devices tested in the chronological order of their development were: (1) a picking reel unit - Model III, (2) a floating-shoe unit, (3) a mowing unit, and (4) a chain-mounted picker-bar unit. These units are described below in a slightly different order because of the relationship between units 1 and 4. The chain-mounted picker-bar unit was developed during the harvest season as the result of field experience with the picking reels. In addition to the harvesting devices, two pieces of equipment for shaping the strawberry row were constructed and tested. These machines also are described below.

Floating Shoe

The intent of the floating shoe harvesting device was to capitalize on the long, relatively limber fruiting-structure characteristics of the Northwest strawberry. A single isolated plant will set fruit around its entire periphery. As the plant spacing in the row is reduced, the proportion of the fruit set on the sides of the row is increased. As envisioned, the device would have a pivoted shoe located on each side of the row. As the machine moved along the row, the leading end of the shoes would follow the contour of the ground and slide under the fruit-bearing trusses. The forward travel of the harvester would cause the trusses to be lifted off the ground. When the trusses reached a predetermined position on the shoe, they would be cut off by a pair of sharpened circular disks. Each shoe was provided with an independent conveying system to transport the severed fruiting trusses away from the cutting mechanism. A traveling brush arrangement was used to assist in moving the plant material from the pick-up point back along the shoes and eventually onto the conveyors. On the field unit, an electrically powered hedge trimmer was substituted for the circular disks.

Field test results did not correspond to the findings of preliminary model studies conducted prior to the regular harvest season. The field unit was not capable of operating satisfactorily with fully matured plants. Consequently, tests were discontinued and the unit was abandoned.

Mowing Unit

Whereas the floating shoe was intended to harvest the berries located on the sides of the row, the mowing method of harvest was proposed as a means of cutting off the entire plant just above the crown. By collecting the severed material in some suitable manner, all of the fruit present on the plant at the time of harvest would be retrieved, thereby resulting in minimum fruit losses.

A number of different cutting devices were tested. The first was a forage-plot harvester belonging to the Oregon State University Farm Crops Department. The cutting mechanism of the plot harvester was a reciprocating knife. It was a scaled-down version of a standard mowing machine cutter bar. Although the cutter bar assembly was in good mechanical condition, its performance in cutting off strawberry plants made it totally unacceptable because of a continual build-up of plant material on the points of the fixed guards.

A search for other cutting devices was conducted. Three electrically powered hedge trimmers were selected for field tests. All three units were capable of cutting off strawberry plants. One of the hedge trimmers was considered to be superior to the others because it permitted a much greater rate of travel down the row. This unit had two reciprocating knives and no fixed guards. As the result of preliminary tests, the double reciprocating knife unit was selected for use in further studies. It comprised the cutting mechanism of the mowing unit which was later constructed. A motor-generator unit was mounted on the harvester to provide power for operating the hedge trimmer. Two pea lifters were attached to the cutter bar assembly to lift the fruit-bearing trusses off the ground ahead of the reciprocating knives. A 12-inch-wide wire mesh belt was provided to move the plant material away from the cutting mechanism.

The test unit was successful in demonstrating the possibilities of cutting off the entire plant as a method of harvest. There were several deficiencies in the operating characteristics of the test unit, however. The hedge trimmer was able to cut off the plants, but its capacity limited the ground speed of the harvester. Its construction was not sufficiently rugged to permit prolonged field operation. Difficulties were encountered in picking up the low-growing fruiting trusses. The forward motion of the machine was not sufficient to prevent a build-up of severed plant material on the cutter bar. Even though the wire mesh conveyor belt was within 2 inches of the cutting edges of the reciprocating knives, it was necessary to provide mechanical assistance to move the severed material from the cut-off point onto the conveyor belt. The 12-inch-wide wire mesh conveyor belt, the harvester's pneumatic cleaning system, and its bucket elevator proved to be inadequate to handle the large amounts of plant material encountered.

Field work on the mowing method of harvest continued after the regular strawberry season by utilizing plant material from the strawberry breeding program. Although no fruit was available, the mature plants permitted tests to check the performance characteristics of different lifter arrangements. The success of this harvesting method is dependent, among other things, upon being able to raise the fruit-bearing trusses above the cutting mechanism.

These tests were conducted at the Lewis Brown Horticulture Farm on July 15. On August 11, a commercially available cutter bar was tested at the North Willamette Experiment Station. This cutter bar had two reciprocating knives and did not require any fixed guards. It was quite similar to the hedge trimmer mentioned above except that standard, full-size mower knives were used. The cutter bar was part of a tractor-mounted mower and did an excellent job of cutting off the strawberry plants. Data were obtained from the operation of each of the units mentioned and will be helpful in the design of a new mowing device to be field tested in 1970.

Picking Reels - Model III

A full-row picking unit is comprised of two picking reels -- one on each side of the row. Figure 1 gives a cross-sectional view of such a unit. With the reel-type harvesting device, there is a space adjacent to and immediately above the crown of the plant which cannot be reached by the picking fingers. As a consequence, any fruit located in this area is missed and contributes to a reduction in the effectiveness of the harvesting device. In cross-section, the area missed by the fingers is approximately triangular in shape as indicated by the crosshatching in Figure 2. Several approaches may be taken to reduce this area and thereby reduce fruit losses. One would be the use of smaller diameter picking reels. Another would be to give the row a shape that would conform more closely to the path of the picking fingers (Figure 3). Both approaches were investigated in 1969.

Two pieces of row-shaping equipment, a contour sled and a contour roller, were constructed and tested. The contour sled was a ridge-forming device for use on established strawberry rows. It was built in two sections. Special provision was made for clearance between the two halves so that the rows could be ridged without damage to the plants. Adjustable angle scrapers were provided to move soil from the row center toward the plants. The resulting row profile had proportions which could accommodate the picking reels. The contour roller was then used to compact the loose soil around the plants and to complete the row-shaping process.

In some instances, the sled was not used because a sufficient amount of soil had been deposited adjacent to the plants during normal tillage operations. Use of the contour sled did produce more uniform row profiles, however.

Several benefits were derived from the use of the row-shaping devices in addition to reducing the area above the plants which normally could not be reached by the picking fingers on an unshaped row. Improved berry pick-up characteristics of the picking fingers were attributed to the smoother soil surface as was the reduction in the number of clods of dirt picked up during the harvesting operation. Firming the soil adjacent to the plants appeared to be beneficial in helping to keep the plants upright and to anchor them more solidly in the ground, thereby reducing the pull-out of plants during the harvesting operation. There also was some indication that the row-shaping treatment made the fruit more accessible for hand picking.

A new set of picking reels was constructed which differed from the 1968 model in several respects. They were shorter, smaller in diameter, had 0.25-inch diameter fingers with an 0.625-inch spacing between fingers, and were not adjustable so far as their spacing and angular orientation with the row was concerned. Positive drive chain conveyors in the center of each picking reel replaced the cleated belts used previously. Depth-gauge wheels were installed to assist in controlling the distance of the picking unit from the ground.

The strawberry varieties and selections included in the field tests were Northwest, Siletz, Hood, Tioga, Molalla, WSU 1224, WSU 1232, and WSU 1239. Quantitative data were not collected from field tests involving the Siletz

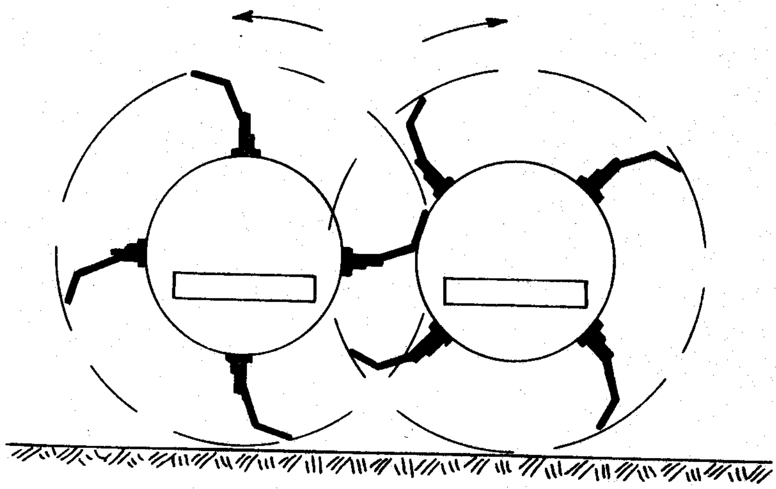

Figure 1. The picking reels of the one-row unit shown in cross section are 20.5 inches in diameter.

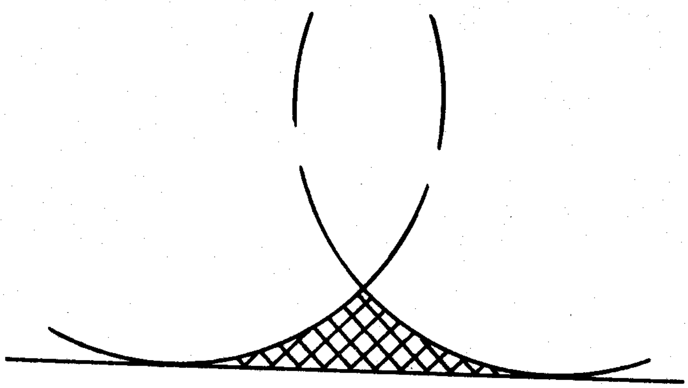

Figure 2. Berries located within the crosshatched area cannot be reached by the picking fingers.

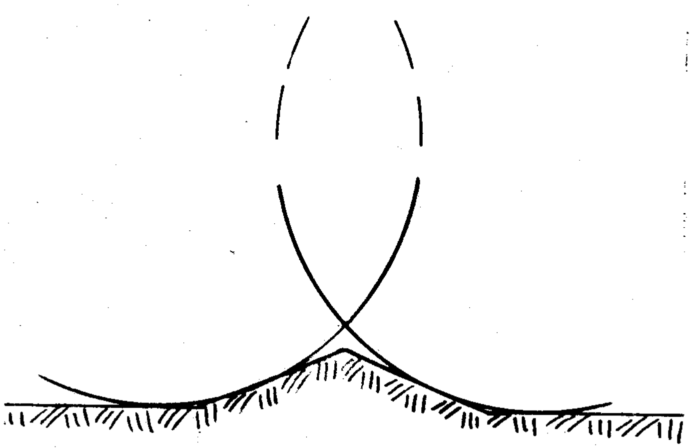

Figure 3. Properly shaped rows can improve the effectiveness of the picking reel harvesting device.

and Molalla varieties. The Siletz berries were overripe at the time of harvest, and there were too many runners and runner plants in the Molalla plot to permit satisfactory operation of the harvester.

The picking capabilities of the 1969 set of reels greatly exceeded those of any of the previous models. In most instances, 95 to 100 percent of the fruit was removed from the plants. Unfortunately, the retrieval rates did not compare with the picking rates. Large numbers of the detached berries were dropped onto the ground. Some of the berries fell to the ground because they missed the conveyors as the picking fingers were being unloaded. Others were carried over in clusters and were dropped onto the ground between the rows. Typical harvest results are shown in Table 1.

Table 1. Harvest Results of Picking Reel Tests Conducted at the North Willamette Experiment Station (June 12-13, 1969)

Strawberry variety	Total season yield on replicated hand-picked plots	Fruit recovered in a once-over machine harvest			
		Non-ridged rows		Ridged rows formed by special row-shaping tools	
	tons/acre	tons/acre	percent of total yield	tons/acre	percent of total yield
Northwest	4.5	2.3	52	3.3	74
Hood	6.2	3.6	58	3.0	49
Tioga	4.9	---	--	3.4	69
WSU 1224	6.3	---	--	4.4	70
WSU 1232	7.2	---	--	4.6	64
WSU 1239	5.1	3.0	59	2.8	55

Field conditions affected picking as well as fruit retrieval. As indicated in Table 1, retrieval rates were generally higher on rows which had been shaped specially for the picking reels. Effective operation of the picking reels required better than average runner control. The presence of runners and runner plants caused the fingers to become plugged with vegetative material. As a consequence, the fruit-unloading characteristics of the picking fingers were impaired and fruit losses were increased. A set of free-rolling circular cutters was installed to help remove the vegetative material that became lodged between the fingers. The cutters were fastened to a shaft which was parallel to the axis of the picking reel and were spaced so there was one cutter for each space between any two adjacent fingers. This method of cleaning the fingers was found to be inadequate.

Tests were conducted with different picking reel rotational speeds. The range used was 10 to 22 rpm. Within this range, picking reel speed seemed to have little effect on removing fruit from the plants. However, fruit losses were less at the lower reel speeds.

Not all strawberry varieties may be suitable for harvesting by the picking reel or other devices with similar picking action. Plants of the Hood variety, for example, do not appear to have adequate strength to withstand the combing action of the picking fingers. Excessive crown breakage was observed in the harvesting tests of this variety.

Chain-bar Unit

The fourth and last picking device tested during the 1969 harvest season consisted of a unit in which the picker bars were attached to two strands of roller chain. The unit was constructed near the end of the harvest season, and its design was influenced by observations of the picking reel operation. A somewhat simplified schematic diagram of the unit is shown in Figure 4.

The primary purpose of mounting the picker bars on chains was to improve the inherently low fruit recovery rates associated with the picking reels.

The modification in picker bar mounting approximately tripled the unloading portion of the finger-travel cycle. The picking action of the harvesting device, so far as finger travel through the plants was concerned, was identical to that of the picking reels. The path followed by the ends of the picking fingers is represented by the dashed lines in Figure 4. Finger size, shape, and spacing on the chain-bar unit were identical to those used on the picking reels.

Fruit recovery rates were noticeably improved. Data collected on one test indicated an average recovery rate of 78 percent on non-ridged rows as compared to recovery rates of less than 60 percent for the picking reel.

From observations made during field tests, it was determined that berries were being dropped onto the ground from at least two locations. Some berries were dropped back through the picker bars onto the row. Others were either lodged between the fingers or were carried over in clusters and dropped off the fingers as the picker bars negotiated the upper outboard turn in traveling around the conveyor. On September 8, the harvester was moved to the North Willamette Experiment Station to test a rotating brush device for removing plant material from the picking fingers. Nisqually berries were used in this test. Work on the brush unit is being continued.

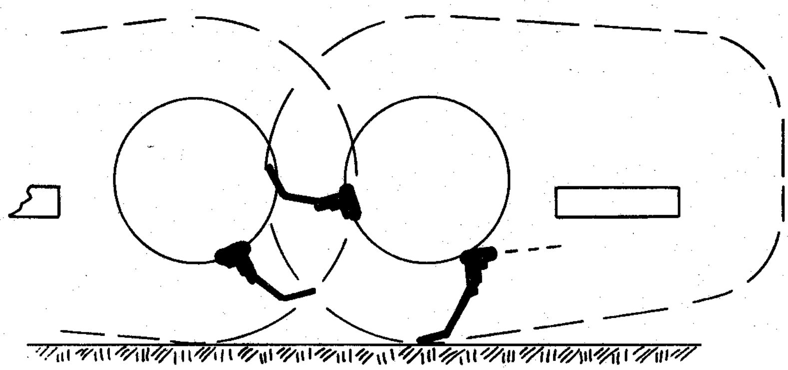

Figure 4. Each half of the chain-bar picking unit has six picker bars.

QUALITY STUDIES ON MECHANICALLY HARVESTED STRAWBERRIES

The effects of mechanical harvest on the processing characteristics and fruit quality of certain strawberry varietal lots was investigated by personnel of the Food Science and Technology Department. Six lots of mechanically harvested berries were supplied for the studies from once-over picking trials on plots of Northwest, Siletz, and Tioga varieties and two Washington State University selections. Five of the lots were harvested with the picking reel unit and one by the chain-bar unit. Since the Siletz berries were considerably overripe at the time of the harvest trial, quality evaluation data for this variety have been omitted. In the case of the Northwest and Tioga trials, hand-picked control lots were supplied to permit direct comparison of harvest methods on fruit quality.

Mechanical harvest effects were investigated in two phases. The first involved sorting and stepwise classification of the fresh fruit in each lot according to:

(1) Categories of associated non-fruit material (calyx, stem, fruit cluster, loose extraneous vegetation, or soil particles).

(2) State of maturity (green, underripe, ripe, overripe). All berries were detached from the fruit clusters prior to the maturity classification.

(3) Types of visible damage by maturity (biological, physical).

(4) Severity of physical damage in fruit of ripe maturity (usable, nonusable).

In the second phase of the study, the ripe fruit separated from the Northwest and Tioga mechanically harvested lots were washed in a McLauchlan vibrating spray washer, capped, and sorted into undamaged, usable damaged, and unusable damaged portions. Sub-lots containing different proportions by weight of usable damaged berries were prepared and processed as a 4 + 1 sliced frozen product. The hand-picked lot corresponding to each mechanically harvested lot was frozen similarly for reference use. After four months of -10° F storage, samples from these processed lots were submitted to the USDA Processed Product Inspection Office at Salem, Oregon, for official USDA grade and mold count. A duplicate set of coded samples was rated for quality by a 12-member panel.

Composition of Mechanically Harvested Strawberry Lots

A percentage composition of selected mechanically harvested lots with respect to non-fruit components associated with the strawberries is given in Table 2.

Table 2. Lot Composition of Mechanically Harvested Strawberries According to Associated Non-Fruit Materials (1969)

	Percent of total lot weight[1]		
Category	Northwest I	Northwest II	Five-lot average
Fruit clusters	5	7	5
Fruit with stems	44	50	51
Fruit with caps	42	38	38
Capped fruit	3	3	3
Loose extraneous materials	6	2	3

[1]Northwest I: 41 lb. lot from the North Willamette Experiment Station.
Northwest II: 132 lb. lot from the Tom Sumoge Farm, Hood River.
Five-lot average includes Northwest I and II, Tioga, and 2 WSU selections.

Component percentages were surprisingly consistent among varieties. Average figures for the five lots indicate that approximately 95 percent of the berries picked by the reel harvester would require subsequent treatment to free the berry from clusters, stems, and caps. Loose extraneous materials, present at about 3 percent in the average lot, also would need to be removed in the preprocessing steps.

Table 3. Maturity Classification of Mechanically Harvested Strawberries (1969)

Maturity class	Percent of total fruit weight[1] Northwest I	Northwest II	Five-lot average
Green	23	10	14
Underripe	20	12	12
Ripe	51	58	56
Overripe	6	20	18

[1] Northwest I: 41 lb. lot from the North Willamette Experiment Station.
Northwest II: 132 lb. lot from the Tom Sumoge farm, Hood River.
Five-lot average includes Northwest I and II, Tioga, 2 WSU selections.

The classification of mechanically harvested strawberries according to stage of maturity is given in Table 3 for individual lots of the Northwest variety and for a five-lot average. These results for some of our present strawberry varieties indicate that 50 to 70 percent by weight of the berries obtained in a once-over harvest with the OSU picking reel unit will be ripe depending on varietal differences in concentration of ripening. The balance of the fruit will be either green to underripe (18 to 40 percent) or overripe (6 to 20 percent) and of relatively low processing value according to current USDA maturity requirements for frozen strawberries. These results emphasize the importance of breeding a productive strawberry with a highly concentrated ripening period before a single-pass mechanical harvesting system can attain economic feasibility.

Determinations of both biological and physical damage present in the ripe berry fraction of the mechanically harvested lots and in the corresponding hand-picked control lots appear in Table 4. Biological damage refers mainly to visible rot and mold. Physical damage refers to evidence of abrasion, tearing, or crushing of the berry tissues by mechanical picking equipment or by finger pressure required in hand picking to separate the berry from the calyx and the pedicel on the plant. The damage records in Table 4 also include further classification of the physically damaged fruit into usable and unusable categories for processing. Berries with usable damage might show surface abrasions, minor cuts or tears, but would be free of embedded soil. The unusable category included severely crushed, broken, or partial berries and berries with embedded soil.

The damage record shows that the average percentage of physically damaged fruit present in the three mechanically harvested lots was more than twice that found in the hand-picked controls, due likely to the abrasive action of the picking fingers and foliage on the ripe berry. A tendency for the physical damage to increase in severity when strawberries were harvested by the mechanical reel unit is shown in the comparative figures for unusable physical damage. In the case of the mechanically harvested lots, an average of 7 percent of the fruit was found unusable due to severe physical damage, while the corresponding hand-picked lots contained no unusable physically damaged berries. The results shown in Table 4 indicate that the replacement of hand picking by the 1969 mechanical reel harvesting unit did not significantly change the percent of diseased strawberries in the lot. However, the mechanical picker appears to produce a two to three-fold increase in the amount of physical injury to the fruit, of which a portion will be rendered unusable for processing.

Table 4. Occurrence of Damage in Mechanically Harvested Versus Hand-picked Ripe Strawberries (1969)

Lot	Harvest method[1]	Ripe berry weight (lbs.)	Percent total damage	Percent damage by type		
					Physical	
				Disease	Usable	Unusable
Northwest I	MH	17	31	1	25	5
Northwest II	MH	75	42	1	27	14
Tioga	MH	22	32	17	14	1
Three-lot average	MH	--	35	6	22	7
Northwest I	HP	14	7	<0.5	7	0
Northwest II	HP	15	23	<0.5	23	0
Tioga	HP	12	21	14	7	0
Three-lot average	HP	--	17	5	12	0

[1]MH = Mechanically harvested; HP = Hand-picked.

The occurrence of diseased fruit in the ripe portion of the mechanically harvested lots did not show a significant increase over the controls, probably because a relatively low incidence of disease was present for all maturity stages except the overripe fruit in these trials. This is apparent in Table 5, where the relative incidence of biological and physical damage according to fruit maturity is reported for the mechanically harvested lots.

Table 5. Occurrence of Damage in Mechanically Harvested Strawberries by Maturity Class (1969)

Maturity	Total fruit weight[1] (lbs.)	Percent total damage	Percent damage by type	
			Disease	Physical
Green	18.2	8	7	1
Underripe	15.1	23	8	15
Ripe	62.5	28	7	21
Overripe	12.0	69	29	40

[1]Fruit weights and damage determined on a four-lot composite including Northwest, Tioga, and 2 WSU selections.

Quality Assessment of Processed Product

Since the Oregon strawberry crop is largely marketed in processed forms, the quality of the mechanically harvested fruit in the final processed product was evaluated by consumer standards. Samples of frozen sliced strawberries were packed experimentally from the ripe strawberry fraction of three mechanically harvested lots (Northwest and Tioga varieties) with known proportions of usable physically damaged fruit varying from 0 to 60 percent. Certified USDA quality grades and mold count values were obtained on six of the specially packed mechanically harvested samples and on samples representing the hand-picked control lots. The results (Table 6) show that all samples submitted to the USDA Processed Product Inspection Service received an A grade. Total scores ranged from 94 to 97 points. Mold counts for selected mechanically harvested samples in this group were quite similar to the corresponding hand-picked samples.

These encouraging results indicate that after berries showing disease or severe physical damage have been removed, the ripe strawberry fraction from the average lot picked by the mechanical reel harvester can produce a USDA Grade A frozen product. Frozen samples duplicating those submitted to the USDA agency for grade also were evaluated for consumer aspects of quality (color, appearance, texture, and flavor factors) by a 12-member test panel selected from staff personnel in the Department of Food Science and Technology and the Department of Horticulture at Oregon State University. In a blind-code, hedonic preference test, the panel indicated a significant preference for the color of the Northwest hand-picked sample over the mechanically harvested samples containing 40 to 60 percent usable physically damaged fruit. The panel also rated appearance of the Northwest hand-picked sample higher than the three mechanically harvested samples containing usable damaged fruit at the 20, 40, and 60 percent levels. The panel failed to distinguish between the mechanically harvested and hand-picked samples with regard to flavor and texture. None of the nine samples in the set were rated unacceptable in overall quality.

Table 6. USDA Quality Evaluation of Mechanically Harvested Versus Hand-picked Strawberries in Sliced Frozen Pack (1969)

Lot	Harvest method[1]	Percent usable damaged fruit in pack	USDA quality: Certified grade	USDA quality: Mold count, percent positive fields
Northwest I	MH	0	A	--
	MH	25	A	2
	HP	7	A	8
Northwest II	MH	20	A	--
	MH	40	A	20
	MH	60	A	--
	HP	23	A	16
Tioga	MH	14	A	18
	HP	7	A	22

[1]MH = Mechanically harvested; HP = Hand-picked.