Efficiency in Fruit Marketing

accuracy and cost of small-sample grading systems for California fruit packing houses

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This article is the second section of Part VIII of a series of reports on the effects of packing-house equipment, plant layout, and work methods on efficiency and costs. These studies have been made co-operatively by the University of California Giannini Foundation of Agricultural Economics and the United States Department of Agriculture under the authority of the Research and Marketing Act of 1946.

Sample grading systems should provide a basis for accurate payments by packing-house management to growers for their fruit—and should limit possible error to within a pre-determined amount.

The more advance information the packing-house management has concerning the expected total season deliveries by each grower, the proportions of fruit falling in particular grades, and the prices for each grade, the more efficiently can sampling systems be designed to achieve a desired degree of accuracy.

As every lot of fruit is received at the plant, a sample—usually several full lugs—is taken for examination. The proportions of the sample-fruit which fall into each grade are used to estimate the proportions of the entire lot. With this procedure, fruit of the various growers may be comingled—pooled—in the handling and packaging processes.

The method of selection of a lot-sample and the size of that sample are two important items to be considered when designing a sample grading system.

The practice of taking several full lugs of fruit at random from a lot is a method of sampling which is commonly used and probably does not give bad results. Mechanical sampling devices which provide convenient and unbiased methods of sampling the entire lot at random would be preferred.

The size of the sample taken from a lot affects the accuracy of the estimates of the proportions of fruit in each grade. Because the distribution of grades of fruit in the sample may differ somewhat from the true distribution of grades for all the fruit delivered by the grower, the estimates will be subject to some error. The magnitude of such differences can be reduced by increasing the size of the sample.

The graph on this page indicates how the per cent of fruit to be sampled from each lot changes with the total deliveries per season or per pool period for several designated degrees of accuracy. The curves in this diagram are based on the assumption that representative samples are obtained and that advance estimates are available concerning minimum season deliveries per grower. Nothing is known or assumed about the probable proportions of fruit falling in each grade.

Accuracy of the estimates is expressed as a per cent of the total weight or number of fruit of all grades and is considered in relation to total deliveries per season rather than for each lot. For example, if the admissible error is to be limited to 1% and the true proportion—for the particular grade to which the error limit refers—is 50% for the season's deliveries, the estimated proportion for this grade may be expected to fall within 49% and 51% in the great majority of the samples.

Basic calculations are made in terms of numbers of individual fruit and are generally applicable to most fruits. Because the quantity of fruit is usually measured in terms of weight, an appropriate ratio must be used to convert to numbers. Gravenstein apples and Bartlett pears, for example, average about three fruit per pound of field-run produce, but Sevillano olives average from 40 to 60 fruits per pound. The lower olive figure should be used estimating the number of fruits delivered by a grower to be more certain of limiting the error to the desired range.

The limits of admissible error shown in the graph on this page represent the upper limits of error that rarely will be reached or exceeded. These limits are based on the probability of obtaining an error of estimates once out of 20 times as large as, or

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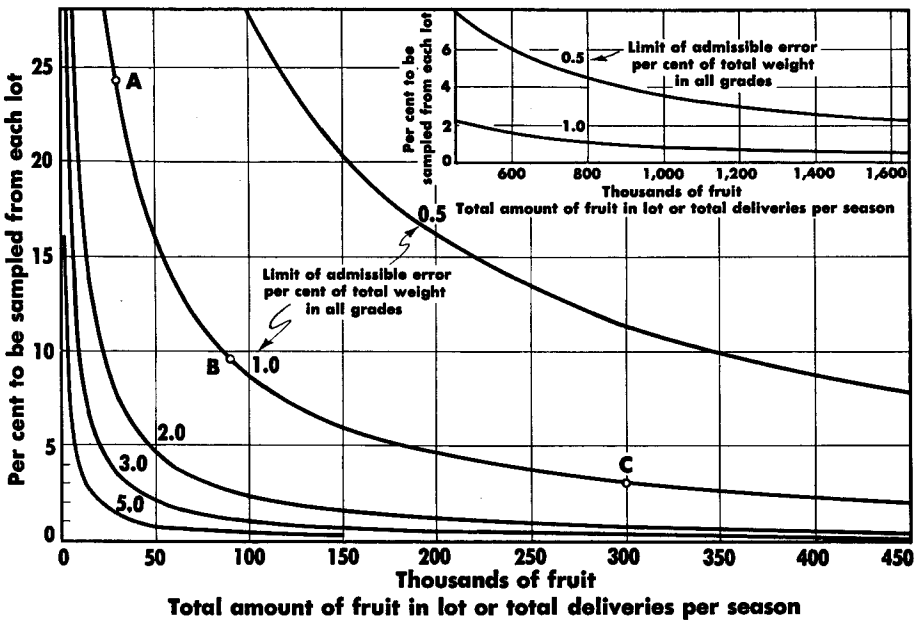

The effect of the desired degree of accuracy and total quantity of fruit per lot or per season on the per cent to be sampled from each lot. If the admissible error is limited to 1% and a grower delivers 30,000 fruits per season the per cent to be sampled from each lot may be found on the graph by reading from the base line at 30,000 fruits, vertically to the intersection *A* on the 1% curve. Point *A* indicates a sample requirement of 24.3%. As the seasonal deliveries increase in amount of fruits the per cent required for a given accuracy in sampling, decreases. With deliveries of 90,000 fruits the same accuracy could be obtained with a sample of 9.6%, *B*; the required sample for 300,000 fruits would be 3.1%, *C*. As the degree of accuracy increases the required per cent to be sampled also increases.

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larger than, the amount specified. This ratio—arbitrarily selected—is commonly used in statistical analysis.

The costs of sample grading include the costs for workers who collect, sort, weigh, tally, and transport the fruit samples and the costs of sample grading equipment which consists of items such as grading tables for pears and apples, sizing-sorting equipment for olives, and scales for weighing the fruit. Mechanical sampling devices for sample selection, used in some plants, are not included in this report.

The costs given in the table on page 13 represent only the annual costs of equip-

The Effect of the Desired Degree of Accuracy on the Volume of Fruit Sampled and the Cost of Sample Grading for Typical Pear, Apple, and Olive-Packing Plants

Deliveries per grower per season	No. of growers	Total deliveries per season	Total sample									
			Limit of admissible error—per cent of total weight									
			5.0		3.0		2.0		1.0		0.5	
1,000 pounds[a]		1,000 pounds	per cent	pounds	per cent	pounds	per cent	pounds	per cent	pounds	per cent	pounds
PEAR OR APPLE PLANT												
30	4	120	0.4	480	1.2	1,440	2.6	3,120	9.6	11,520	30.0	36,000
50	8	400	0.3	1,200	0.8	3,200	1.6	6,400	6.0	24,000	20.4	81,600
100	10	1,000	0.2	2,000	0.4	4,000	0.8	8,000	3.1	31,000	11.4	114,000
150	6	900	0.1	900	0.2	1,800	0.5	4,500	2.1	18,900	7.9	71,100
200	5	1,000	0.1	1,000	0.2	2,000	0.4	4,000	1.6	16,000	6.0	60,000
400	2	800	0.1	800	0.1	800	0.2	1,600	0.8	6,400	3.0	24,000
	35	4,220	0.2	6,380	0.3	13,240	0.7	27,620	2.6	107,820	9.2	386,700
Total sampling cost[b]				$175		$190		$223		$406		$1,042
OLIVE PLANT												
1[c]	5	5	0.9	45	2.5	125	5.6	280	19.3	965	49.0	2,450
5	7	35	0.2	70	0.6	210	1.1	385	4.7	1,645	16.2	5,670
10	10	100	0.1	100	0.3	300	0.5	500	2.4	2,400	8.9	8,900
20	8	160	0.1	160	0.1	160	0.3	480	1.2	1,920	4.6	7,360
50	5	250	0.1	250	0.1	250	0.1	250	0.5	1,250	1.9	4,750
100	5	500	0.1	500	0.1	500	0.1	500	0.3	1,500	1.0	5,000
200	1	200	0.1	200	0.1	200	0.1	200	0.1	200	0.5	1,000
	41	1,250	0.1	1,325	0.1	1,745	0.2	2,595	0.8	9,880	2.8	35,130
Total sampling cost				$192		$202		$222		$397		$1,003

[a] Average of three fruits per pound used to calculate number of fruit.
[b] Costs based on larger-size sample grading table.
[c] Average of 40 Sevillano olives used to calculate the number of fruit.

Costs of Sample Grading Systems in Relation to Degree of Accuracy for California Pear, Apple, and Olive Packing Plants

Plant	Volume per season	Average volume of deliveries per grower		Average cost of sample grading (dollars per 1,000 pounds of fruit received)[a]			
				Limit of admissible error for the average size grower			
				Per cent of the total weight delivered			
				3.0%	2.0%	1.0%	0.5%
	1,000 pounds	1,000 pounds	Estimated 1,000 fruit				
PEAR AND APPLE PACKING HOUSES							
A	3,520	90	270	$0.06	$0.06	$0.13	$0.33
B	2,331	70	210	0.08	0.09	0.17	0.42
L	4,524	115	345	0.04	0.05	0.10	0.27
M	6,385	320	960	0.03	0.03	0.05	0.11
N	5,695	240	720	0.03	0.04	0.06	0.14
R	9,000	320	960	0.02	0.02	0.04	0.10
S	10,300	115	345	0.02	0.03	0.08	0.25
T	8,125	580	1,740	0.02	0.02	0.03	0.07
U	5,745	190	570	0.03	0.04	0.07	0.17
OLIVE PLANTS							
I	487	35	1,400	$0.35	$0.40	$0.47	$0.95
II	1,713	42	1,680	0.12	0.12	0.21	0.62
III	3,100	18	720	0.08	0.12	0.36	1.25
IV	1,527	26	1,040	0.13	0.15	0.32	0.92
V	2,098	46	1,840	0.10	0.10	0.20	0.56
VI	1,218	14	560	0.18	0.23	0.54	1.67
VIII	824	16	640	0.24	0.29	0.56	1.56
IX	2,409	56	2,240	0.09	0.09	0.16	0.52

[a] Costs for pears and apples based on large size sample grading table.

ment and the labor cost per 1,000 pounds of fruit sampled. Total costs of sample grading depend on the quantity of fruit received that is sample graded, which in turn depends on the desired degree of accuracy, the total volume handled per season in the packing house, and the particular distribution of total deliveries among the individual growers. These factors vary from plant to plant. However, the general nature of these costs and their relation to sampling accuracy may be illustrated with reference to the conditions in a specific plant.

Costs for a typical pear or apple packing house and a typical olive processing plant are given in the upper table on page 12. The per cent to be sampled from each lot for each size group was determined for several levels of accuracy from the graph on page 11. These figures were applied to the total quantities of fruit to be sampled for each size group. The columns were added for an indication of the necessary total quantities of fruit to be sampled by this plant to obtain various degrees of accuracy. These calculations, indicate a rapidly increasing quantity of fruit sampled—and thus an increasing sampling cost—with increases in accuracy, especially for higher levels of accuracy.

Following similar procedures, costs of sample grading were estimated for a number of plants now using separate-lot systems. These costs, for several degrees of accuracy, are given in the lower table on page 12. Details as to the season deliveries for each grower were not readily available for every plant, so sampling costs were estimated by using the average volume of deliveries per grower to determine the average per cent of fruit to be included in samples.

Estimated Labor and Equipment Costs for Sample Grading

	Pear and apple plants		
	Volume less than 20,000 pounds per hour	Volume more than 20,000 pounds per hour	Olive plants
Estimated installed cost of sample grading equipment, 1952[a]			
Grading table[b]	$50	$650	$700
Bench scales—dial type	560	560	480
	$610	$1,110	$1,180
Estimated annual cost of equipment[c]	$70	$160	$160
Typical labor hours per 1,000 pounds of fruit in samples	1.9	1.9	20
Typical labor cost per 1,000 pounds of fruit in samples[d]	$2.28	$2.28	$24

[a] Does not include costs of mechanical devices for sample selection.
[b] Table for small pear or apple plants has capacity for two sorters. Table for large plants has powered belts and capacity for four sample sorters. The olive sizing-sorting table has a capacity of about 150 pounds per hour.
[c] Based on a standardized set of annual charges for depreciation, repairs, insurance, interest, and taxes; grading tables, 14.7%; scales, 10% plus $7.50 per year for repairs and maintenance.
[d] Based on typical average wage of $1.20 per hour for sample grading labor.

Sampling costs—per thousand pounds of fruit received—increased with increases in the degree of accuracy. The costs also increased with decreases in the average volume of deliveries per grower and again, because of the fixed costs for equipment, sampling costs decreased as the total plant volume per season increased.

Costs Compared

The cost of a separate-lot system depends on such factors as the length of the break periods between lots, the average size of lot, rates of plant output, and total direct hourly payroll.

Sampling costs are influenced by the desired degree of accuracy, the amount of advance sampling information available, and the distribution of total deliveries among individual growers.

The comparative costs of separate-lot and sample grading systems are illustrated by the bar-graph on page 13.

For pear and apple plants studied, the estimated cost of the sampling system with a limit of admissible error of 1% for the average grower was, in all cases, less than the cost of separate-lot systems, even where the break period was as short as two minutes. Where the admissible error was limited to ½% the cost of sampling was sharply increased. However, even in this case sampling costs were less than separate-lot costs in five of the nine plants.

The case for sample grading was less clear in olive plants. Costs of the separate-lot system per 1,000 pounds of fruit received were generally higher than in pear and apple plants, but so were sampling costs. With 1% accuracy, estimated sampling costs were less than present costs of separate-lot systems in seven of the eight olive plants. Also, they were less than the

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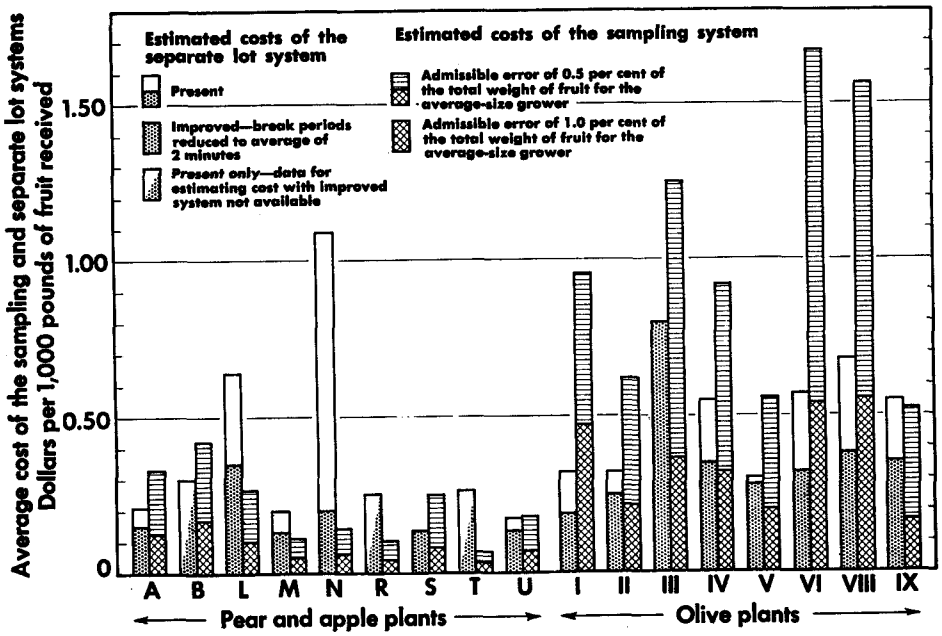

Comparative costs of sampling and separate lot systems in California pear, apple and olive packing plants. Each pair of bars represents a packing plant. The bar on the left indicates the cost of the separate-lot system. The total area of the bar represents the present cost of the separate-lot system, and the stippled area, the estimated cost with two-minute average breaks between lots. Data for break time were not available in plants B, R, and T. The present break time in plants S and III was two minutes or less so no reduction is indicated. The bar on the right of each pair indicates the estimated cost of a sample grading system in the plant represented. The total area of the bar shows the estimated cost of sampling with an admissible error of ½% of the total weight of fruit. The cross-hatched area of the bar indicates the cost of sampling with a 1% limit of admissible error.

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costs of a more efficient separate-lot system with two-minute breaks in five of the eight plants. However, where a limit of admissible error of only ½% was desired, sampling costs were greater than present separate-lot costs in all but one plant.

With a limit of admissible error of 1% or more, the sampling system had some cost advantage in the majority of the plants. Where a higher degree of accuracy was desired, both the present and the improved separate-lot systems were generally less costly than the sampling system.

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Other reports in this series compare house operations, methods, equipment, and arrangements. The comparisons may be used to establish standards for efficient and low-cost operation. With minor modifications, the results of these studies can be applied to many of the problems of packing and processing other fruits and vegetables. For detailed reports, address Agricultural Publications, 22 Giannini Hall, University of California, Berkeley 4, California.

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