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ECONOMIES OF SIZE FOR MAINE POTATO PACKING PLANTS

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PREFACE

This report utilizes the results of several basic studies which have been made during the past several years, some of which have been published and some not. The component studies, such as capabilities of sorting personnel, were conducted primarily by the author and the late Robert A. Ries, Industrial Engineer, USDA, AMS, who were at one time assigned to the Maine Potato Handling Research Center. Case studies and basic data were obtained through cooperation among several potato packing firms in Aroostook County, for which appreciation is expressed. Appreciation is also expressed to several allied industries such as equipment dealers, utility companies, and packing supply firms which cooperated in providing information.

Special thanks are extended to the following who are (or were) with the Department of Agricultural and Resource Economics at the University of Maine, Orono: to Dr. Neil H. Pelsue, Jr., and Dr. Fred J. Benson for counseling in the development of the computer programs; to Dr. Wallace C. Dunham and Dr. Gregory K. White for their critical review of the manuscript; to Gilberte M. Violette who typed the manuscript; and to my administrators for their encouragement and support.

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Economies of Size for Maine Potato Packing Plants

Edward F. Johnston*

INTRODUCTION

Maine has long been known as a major potato producing state. Since 1920, ten to 15 percent of the total United States potato production has been produced in Maine (Table 1). Maine is classed as a fall-crop potato producing state, with most of the crop being placed in storage at harvest and then removed from storage and prepared for market during the 7-9 months following harvest. Most of the potatoes produced in Maine are, and have been, marketed as tablestock (fresh) potatoes. In recent years, about 53 percent of the sales have been as tablestock, with about 38 percent marketed to processing plants and starch factories, and nine percent marketed as seed potatoes (Table 2).

Prepackaging of potatoes in consumer size containers at shipping points became a practice beginning in the 1930's, with the Maine industry being one of the forerunners of the procedure. Shipment to terminal markets was entirely by railroad, thus the packaging was done within storage facilities located at track sidings. Potatoes in farm storage were, therefore, transported to trackside facilities for grading and packaging. In the trackside storage, the practice was to place the grading equipment in the rollways or in the (ground floor) bins of the storage, moving the equipment to the stored supply to accomplish the grading and packing. (Potatoes in cellar bins were hoisted to the ground floor level). In time, some storages were altered with storage space sacrificed to provide a more permanent location for the grading equipment. Eventually, as the size and type of grading and packing equipment changed, some packing facilities were constructed integral with, but separate from, the storage. Equipment was there more permanently located, with the entire supply of potatoes brought from the storage area to the equipment.

Output of packaged product from the combination storage-packing facilities was generally geared to about one unit per day, i.e., one carload per day. Over time a carload increased in size from 36,000

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Table 1

Proportion of United States Potato Production Produced in Maine, 1920-1976

Period	Annual average U.S. Production[1]	Annual average Maine Production[1]	Proportion produced in Maine
	million hundredweight		Percent
1920-29	216.7	21.0	10
1930-39	217.6	26.1	12
1940-49	245.5	35.9	15
1950-59	234.5	34.6	15
1960-69	283.5	36.6	13
1970-76	321.7	32.3	10

[1] Determined from annual and monthly reports of Statistical Reporting Service, U.S.D.A.

Table 2

Market Distribution of Maine's Potato Crop, 1970-1975 Averages[1]

Market Channel	Thousand Carlot equivalent[2]	Percent
Tablestock	24.2	52.8
Processing	17.3	37.7
Seed	4.4	9.5

[1] Determined from Federal-State Market News Annual Reports, Presque Isle, Maine

[2] Carlot = 550 hundredweight

pounds to as much as 60,000 pounds. Since 1966, truckloads of 40,000 to 48,000-pound capacity have become the predominant shipping unit, however. Within the past two decades, a few packing facilities have been constructed in which the production output might be three to six carlot equivalents per day.

There has been interest for some time in the Maine potato industry in what has been termed "centralized packing." The King, Grant and Micka study (1) indicated nine centralized and strategically located packing plants could provide the necessary tablestock packing facilities for the entire state. The Maine potato industry continues to be catagorized as "a large number of small plants," however, as preliminary results of a survey conducted in 1976 (2) indicate:

1. Of 866 shippers who reported their seasonal output, about 52 percent packed 30 or fewer truckloads per season, while about 5 percent packed 200 or more truckloads per season.
2. Of 359 shippers who reported rate of packing in small packages, about 80 percent packed one truckload per day, while less than 5 percent packed three or more truckloads per day.

With the increase to a predominance of truck transportation in lieu of rail, a considerable amount of packing is now done at "farm" storages or at facilities located off-track. By number, about 58 percent of the packing facilities reported in the 1976 survey were located off-track.

Ten-pound packages are the predominant size package used in marketing Maine tablestock potatoes (3). In recent years, 38 to 45 percent of shipments have been in ten-pound packages, with 10- and 5-pound containers accounting for 45 to 50 percent of the total. Most tablestock potatoes shipped from Maine are round - white varieties (Katahdin, Kennebec, Superior, etc.), with 10 percent or less of the total being the long-white variety, Russet Burbank.

In the grading and packing process, potatoes must be processed to accomplish certain objectives. Most of these objectives are stipulated by the standards of the grade in which the potatoes are to be marketed. Grade standards are promulgated by either federal or state regulatory bodies, or both. Therefore, the potatoes are sized to meet, as a minimum, the size specifications of the grade. They must meet minimum specifications regarding the amount of dirt they contain and therefore may be dry-brushed or washed. The potatoes also must be sorted (graded, racked, or culled are other terms for this process), to remove mechanically damaged, diseased, or otherwise affected tubers to a level within the tolerance specified in the grade. The sized, cleaned, and graded potatoes are then packaged in containers marked with the grade, and the containers are closed. Containers of 5- or 10-lb. capacity are often placed in a master container of about 50 pounds content. The containers are then moved into the transport vehicle. Sizing and cleaning are generally done completely by mechanical operations, sorting is predominantly a manual operation, and packaging ranges from a predominately manual to an almost entirely mechanical operation.

PURPOSE AND OBJECTIVES

To remain competitive in the fresh potato market, the Maine potato industry must provide, consistently, tablestock potatoes of desired quality while being as economically efficient as possible. Accomplishment of each of these goals would be enhanced by movement of these operations to fewer and larger packing facilities than currently exist in Maine. Quality maintenance and control measures are generally promoted by a volume of business that will enable diversity and specialization, and various efficiencies are obtained as volume of activity is increased.

Each combination of handling and packing equipment has a maximum practical capacity at which it may operate. To obtain a greater output, larger and/or more equipment, and/or more manpower, must be utilized. Since "centralized packing" facilities may be desired at some unknown level of output, or at different specified levels of output, the economic appraisal of several sizes of round-white potato packing facilities is desirable.

The objectives of this study were to:

1. Develop from maximum practical handling capacities, the most economical combination of equipment to handle, grade, and package round-white potatoes with input rates ranging from 80 to 800 cwt per hour.
2. Develop representative unit costs when packing a representative mix of container sizes at input rates ranging from 80 to 100 cwt per hour.
3. Develop measures of the influence of several input factors on the level of unit costs.
4. Provide information which can be used as a guide for decisions in making adjustments and in planning new packing facilities.

RESEARCH PROCEDURE

The basic criteria in this analysis of fresh-pack potato packing plant size were that the supply rates under consideration would range from 80 to 800 cwt per hour, and that the output could contain a mixture of bag sizes. The operations included in the analysis are those involved in packing and loading round-white potatoes, beginning with the removal of the potatoes from storage and their supply to the packing line; including the cleaning (washing), sizing, sorting, and packaging; and ending with the transporting vehicle filled, closed, and ready to move to market. Included also are supplies and materials, and the office and clerical functions performed at shipping point to move shipments into the marketing channels. The packing facility is assumed to be separate from, but integral with, the storage. The packing facility is included in the analysis, while the storage facilities are excluded. The model operations are synthesized, but have been designed to be representative of actual operations.

Data were collected for each size and type of equipment that would be used in the models, including the motor size used, the price at 1974-1975 levels, and manufacturers' estimates of both the expected useful life of the equipment and its capacity. A practical maximum capacity for each piece of equipment was assigned, based upon the manufacturers' estimates, research studies, and observation and measurement in commercial grading and packing operations.

Labor requirements and practical maximum capabilities of labor were established through time study methods, and were assigned to each machine and operation, conditioned by the handling rates of the equipment. A file was established for each category of equipment, with associated labor included, arranged in an ascending order based on maximum practical capacity. (Appendix A, Tables 3 and 4 are examples of such a file.) A computer program was developed (POPACK I) to analyze the supply rate and the portions removed as the flow progresses through the packing line, and to determine the rate of flow into each piece of equipment or phase in the line. The program then selects a specific piece of equipment from the appropriate file by pairing the lowest capacity machine capable of handling the flow with the flow rate into the machine as previously determined. Often this procedure also resulted in selection of the least-cost combination of equipment and labor. Exception occurred, however, in bagging arrangements where the selected manually-operated equipment and the associated labor resulted in a higher per unit cost than would a higher capacity semi-automatic bagger with fewer laborers.

To analyze the costs resulting from a packing line as selected by the POPACK I program but with other selected bagging arrangements, a second computer program (POPACK II) was developed in which each piece of equipment was specified rather than selected. Comparisons could then be made to select the equipment combination which resulted in the least-cost combination for the specified supply rate.

Selection for least-cost bagging equipment is conditioned by the number of days of operation as well as the flow rate to the bagger. For relatively short packing seasons, manually operated bagging arrangements prove lower in unit cost than are the more automated bagging arrangements. By changing the two variables—days of operation and supply rate—in computer programs, break even points for capital-labor substitution were found. The analysis showed, that for 10-lb bags under the assumed price and wage level, the manually operated bagger was the lower cost arrangement when the bagging rate was 142 cwt/hr or less, regardless of the number of days that the packing line operated. With a bagging rate of more than 142 cwt/hr, use of the manually operated bagger produced lower costs for up to 123 days of operation at which point the use of the 16-head rotary bagger with automatic bag hanging and closing attachments became the least-cost arrangement. The same results occurred with the next higher (161 cwt/hr) capacity equipment setup. With the next higher capacity combination at 182 cwt/hr bagged the rotary bagger resulted in lower costs after 73 days of operation. For bagging rates of more than 182 cwt/hr, manually operated baggers resulted in least-cost operations only when a low number of operating days (fewer than 60) was considered.

Resulting total cost for a packing line was obtained by adding costs of individual units; no attempt was made to elicit from manufacturers a unit cost for a complete packing line. Among input variables which could be changed, in addition to those given above, were portions off-grade, bag breakage, operating time as a percent of overall time and length of operating day. These variables were held constant, while the variables mentioned earlier were changed in order to select the equipment under the assigned conditions.

As the specified rate of supply was increased from 80 to 800 cwt/hr, ten basic grading line combinations and four sizes of packing house facilities were developed to accommodate the flow. These basic lines were developed from the practical capacity of the specific combination of equipment: chain sizer, washer-dryer, grading table, and spool sizer. One of each of the supply and the bagging arrangements, combined with the sizing, sorting, and cleaning equipment allowed for the maximum capacity of the basic line. At certain flow rates below the maximum, the substitution of lower capacity and lower cost supply equipment and/or bagging equipment used in combination with the same sizing, sorting, and cleaning equipment would result in a lowering of unit costs.

Whereas the POPACK I program considers the packing of only one bag size in the equipment selection process, equipment for bagging 50-lb bags was obtained separately from equipment for bagging 10-lb bags (the latter may be used to pack 5-lb and 20-bags as well). Least-cost arrangements for packing 50-lb bags under specified conditions were also obtained through multiple analysis with the program and subsequent selection. Packing equipment for both 5- to 20-pound bags and for 50-pound bags is necessary to result in a packing facility that can produce output in the various size containers when semi-automatic baggers are used.

The second computer program (POPACK II) was developed not only to analyze cost of output when 100 percent of the product was in one given bag size, but also to analyze costs of a product mix—that is, when any combination of 5-, 10-, 20-, and 50-pound bags was included in the output of the packing line. Least-cost combination of equipment for packing the predominant bag size, as selected by the initial analysis, was used in the second program, with specified proportions of the operating time being allocated to each of the four-bag sizes. Cost curves were developed for each of the packing line combinations, beginning with maximum supply rates and then decreasing the supply.

The effects of several of the variables were obtained by altering the input values. Standard base values used to establish model costs are given in Appendix A, Table 1, or in the "Assumptions and Specifications" section.

ASSUMPTIONS AND SPECIFICATIONS FOR MODEL PLANTS

The Product

As noted in the introduction, Maine potatoes for tablestock are typically round-white varieties which are stored as field-run potatoes until they are prepared for market. A standard level for the quality of stored potatoes was assumed for this report and is considered representative, while it is acknowledged that variation in the size distribution and in other quality characteristics occurs among stored lots of potatoes in any year, and from year to year. Of the potatoes supplied to the packing line, 10 percent were assumed removed from the flow in the sizing process as under minimum size for the grade. Ten percent of the quantity supplied was assumed removed by sorting personnel as grade defective.

All graded and packaged product was assumed washed in the handling process.

Of the graded product, 14 percent was considered packaged separately in 50-lb bags as the Maine grade "Chefs Special." Potatoes in this grade have a size range of 3 to 4 inches in diameter. The consumer package, therefore, whether in 5-, 10-, 20-, or 50-lb bags, was assumed to contain US No. 1 quality potatoes within the size range of 1⅞ to 3 ¼ inches diameter.

The Packing Building

The facility for housing the packing equipment and operations is considered separate from, but integral with, a storage facility. To accommodate the packing lines selected, four sizes of buildings were used: 4,000 square feet, 6,500 square feet, 10,000 square feet, and 12,500 square feet. The building is assumed to be of metal construction. Based upon recently constructed buildings, contractors handbooks, and municipal records, costs of these buildings to represent 1974-1975 levels were assessed at $9.78, $9.23, $8.68, and $8.28 per square foot, respectively. Of the ten model packing lines developed, the smallest of the buildings would house either of two of the basic lines, the largest of which has a 263 cwt/hr input capacity. The next size building would house either of two of the lines, the largest of which has a 427 cwt/hr input capacity. Four of the basic lines could be housed by the 10,000 square foot building, the largest having a 665 cwt/hr input capacity. The largest building accommodates either of the two largest capacity lines used in the analysis.

The Supply System

The bulk scoop method of supplying the packing line was selected for use in the analysis. Six sizes of bulk scoops are assumed available, the capacities being 165, 330, 495, 660, 825, and 1,000 pounds of potatoes. The supply rate capabilities of bulk scoops depend on the distance between the pile of potatoes and the hopper into which they unload. Through time study data obtained by studying operations of several commercial packing lines, representative time requirements to load, travel loaded, empty, and travel empty were found for bulk scoops of the various capacities. Capabilities are shown in Figure 1. Possible methods used to increase the supply capability of a given size bulk scoop include (1) use of flat belt conveyors between the hopper and the grading equipment, (2) utilizing portable hoppers, or (3) utilizing a second bulk scoop. Alternating between a "near" bin and a "far" bin is a technique which could facilitate the removal from distant bins yet

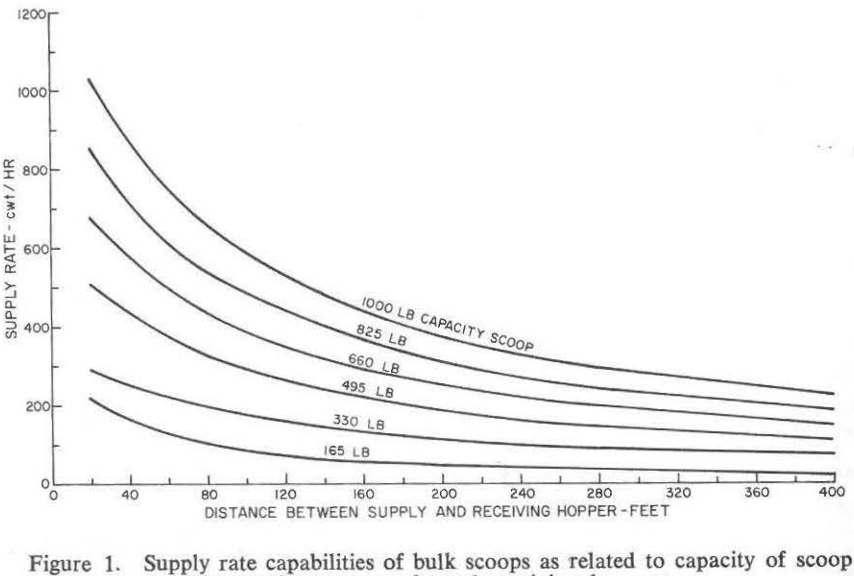


Figure 1. Supply rate capabilities of bulk scoops as related to capacity of scoop and distance between supply and receiving hopper.

maintain a supply rate higher than that of supplying from a distant bin alone.

The capacity of the attached storage influences the maximum distance that exists between the supply source and the packing line. The storage capacity does not necessarily influence the total volume for a packing line during the shipping season, however, as potatoes may be transported from storages at other locations for grading and packing.

The complexity of the situations in determining the least-cost supply system demands a separate analysis. One study has been published (4). A simplified approach was taken to develop the cost of supply for this analysis. It was assumed (1) that as supply rate increases, the attached storage size increases, and (2) that ⅔ of the storage is required to be supplied at the prestated flow rate. A supply rate of 400 cwt/hr from a maximum distance of 186 feet can be accomplished with a 1,000 lb capacity bulk scoop. For rates or distances in excess of these, some alternative methods, such as previously mentioned, must be employed. For the purposes of this analysis, use of a 20-foot conveyor between the receiving hopper and the grading line was assumed to attain a 400 cwt/hr supply rate. Rates from 400 to 600 cwt/hr were assumed to require 150 percent of the investment of a 1,000 lb capacity bulk scoop setup, and rates from 600 to 800 cwt/hr to require twice the investment. It was further assumed that the receiving hopper hold at least 10 times the capacity of the bulk scoop. The results of these assumptions are given in the Appendix A, Table 2.

The Grading System

The equipment in the grading section, consisting of a chain sizer, washer-dryer, sorting table, spool sizer, and distribution tables was selected on the basis of handling the maximum capacity of the "bottleneck" piece of equipment—usually the washer-dryer, although at times the ability of the sorting personnel became the limiting factor. A further stipulation was that no piece of equipment would feed directly onto another piece that was narrower by more than 6 inches. For example, a 48-inch wide washer-dryer would not feed directly onto a 30-inch wide sorting table. Equipment is allowed to feed onto wider equipment, and this occurs in arranging least-cost setups. That is, a 24-inch wide chain sizer may precede a 36-inch washer-dryer because it is capable of handling the maximum capacity of the washer-dryer, and it is lower in cost than a 36-inch wide chain sizer.

Minimum width for equipment in the grading section was set at 24 inches, and a maximum width at 60 inches, with the exception of the sorting table. For undivided sorting tables, which utilize sorters on both sides, a maximum of 30 inches width was set. For divided sorting tables, the maximum width for each grading lane was set at 22 inches. In no case was a flow of potatoes allowed to be inspected and sorted by only one worker. Maximum practical capacities of grading equipment are given in Appendix A, Table 3.

The number of sorting personnel required at the grading table to inspect the flow and remove off-grade potatoes is influenced both by the rate of flow and the quality of the potatoes. Studies were made of inspecting and sorting rates when packing round-white potatoes, and maximum capabilities for sorting personnel in this report were assigned from these studies. The rates are given in Appendix A, Table 4, and are expressed graphically in Figure 2. If 30 percent of the potatoes flowing to the sorting table needed to be removed, two sorters would be required were the flow rate 100 cwt/hr (or less). The limitation encoun-

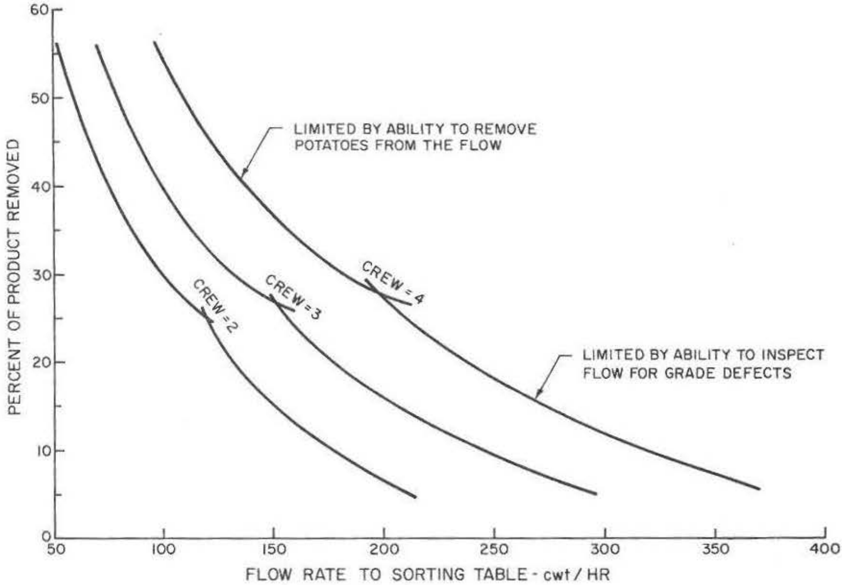


Figure 2. Maximum rates handled by sorting personnel when inspecting the flow and removing off-grade potatoes.

tered is the ability to inspect and decide which tubers are off-grade. Four sorters could handle a maximum of 183 cwt/hr of the same quality potatoes limited, also, by ability to inspect. Were 10 percent of the flow to the sorting table to be removed, a crew of two sorters would be required for flow rates up to 178 cwt/hr. The limitation encountered is the ability to grasp and discard the off-grade tubers. A crew of four sorters could handle 320 cwt/hr of the same quality potatoes. To handle rates of this quality potatoes in excess of 320 cwt/hr to be sorted, an additional sorting table and additional personnel are required.

The Bagging and Baling System

The bagging equipment considered for analysis was of two types: (1) manually operated, and (2) semi-automatic. The manually operated equipment requires a worker to operate a foot pedal which controls the flow of potatoes into the container. In addition to the filling machine, scales and a container closer are required. The filling machine may have one, or multiple "heads" at which containers may be filled. The process of filling, weighing, and closing may be accomplished by from one to five persons on a two-head machine. Ten persons for a manual packing station were considered as maximum. Manually operated bagging equipment can be used to fill all bag sizes.

The semi-automatic bagger considered in this analysis is that which is commonly referred to as the "Baker Bagging Machine." It is a rotary type machine with 10, 14, 16, or 18 bagging heads. Each of the bagging heads has an integral scale. Bags, placed manually or by equipment on the bagging heads, are filled with a pre-determined weight of potatoes. The weight is checked and corrected by the checking personnel, and the bags are deposited, manually or by equipment, for closing. The equipment considered in this analysis would be capable of handling bag sizes up to 25 pound contents.

Bagging of 50-lb containers was assumed to be done on a manually operated bagger, and where smaller bag sizes were to be filled, both types of bagging equipment were assumed to be required.

The maximum capabilities of the various number of bagging, weighing, and closing personnel with either type of bagging machine are given in Appendix A, Tables 3 and 4. These rates were determined primarily from time study data obtained at several commercial packing operations in Maine.

An analysis was made of the several bagging arrangements to obtain the least-cost arrangement for various lengths of packing season. In some cases, a relatively short season would specify a manual operation whereas a longer season would specify a semi-automatic operation.

For bag closing equipment, two types were included, one for closing paper bags and another for closing film (polyethylene) bags. Two closing machines for closing paper bags are required if both 50-lb bags (including "Chefs Special" bags) and smaller size paper bags are packaged.

Five- and 10-lb poly bags and 5-lb paper bags are generally placed in a master container, or baler bag, which will contain ten 5-lb or five 10-lb bags. Ten-pound paper bags often are baled also.

Equipment for baling the small containers consists primarily of a flat, circular, rotating table, from which the small packs are manually removed and placed in the master containers, plus a machine to close the master bag. It was assumed that a maximum of 5 persons could work at one baling unit. The rate of baling is influenced both by the size of the small container and the material of which it is made. Maximum practical capabilities for various numbers of baling personnel when baling 5- or 10-lb bags, of paper or poly material, are given in Appendix A, Table 4.

The net weight of potatoes in each of the bag sizes is given in Appendix A, Table 1, as is the loss in containers because of bag breakage and for other reasons.

Ten-pound bags were found from recent historical data to be the predominant size container for Maine tablestock shipments. The labor and equipment combinations found by analysis to be the most efficient while packing 10-lb. poly bags were used in developing the model packing lines in this report. Other combinations may be most efficient while packing other size containers.

The Loading System and Miscellaneous Equipment

One of the most common systems for loading the transporting vehicle is to move containers from the closing station to, or into, the carrier with the use of conveyors. At, or in, the carrier, the containers are manually removed from the conveyor and placed in tiers.

For this analysis, it was assumed that the maximum practical capability of the loading crew is the same when loading 20-lb bags as for 50-lb bags or master containers. The maximum rates assessed are given in Appendix A, Table 4.

The miscellaneous equipment that is often used in a packing operation may include such items as portable heaters, alternative or spare closing machines, tarpaulins, barrels, tools, pumps, shovels, alternate sizing screens, etc. To account for the cost of such equipment in a packing operation, a sum equaling 2.5 percent of the cost of the major pieces of packing equipment was found representative in case studes and was selected for this analysis.

Utilities

It was assumed that an L.P. gas operated bulk scoop is used in the supply system, that the potatoes are washed in the packing operation, and that the costs for lights and heat would be charged at a rate equal to the power requirement for operating the packing line equipment (this was determined from case studies). Utilities, therefore, include electricity, L.P. gas, and water.

To determine the electricity requirement, the horsepower requirements of the component pieces of the packing equipment were totaled. Based upon case studies, the kilowatts drawn were assessed on the basis that one horsepower would equal one kilowatt of electricity. Kilowatt-hours of electricity used per day by equipment were found by multiplying the total horsepower by the length of the working day, times the percent of operating time assumed. Kilowatt-hours used for lights and heat were found by multiplying the total horsepower by the length of the working day plus one hour.

Cost for electricity was assessed at rates similar to those in effect in Northern Maine in 1974-75, and is given in Appendix A, Table 5. To enable the use of this rate structure, a month was assumed to be 25.5 working days. (Average over 6-8 month season when on a 6-day week).

The consumption of L.P. gas by bulk scoops was studied and a rate of gas consumption was determined for each of the size of scoops used in the analysis. Cost for gas was assessed at rates similar to those in Northern Maine in 1974-75, and these are given in Appendix A, Table 5.

The charges for water were determined assuming a well as the water source. The quantity of water needed to be available was assumed at the rate of 1 cubic foot of water (7.5 gallons) per hundredweight of potatoes input. Through interviews with well drilling companies and analysis of data published by the U.S. Department of Interior on ground-water in the lower Aroostook River Basin, the depth, yield, cost of drilling, and size and cost of pumps to produce various volumes of water were determined. The results of the analysis and the costs assumed are given in Appendix A, Table 5.

Depreciation, Repair, Interest, Taxes, and Insurance

Depreciation of buildings and equipment was determined in general on a straight line basis, dividing the cost by the useful life. For equipment, however, the assessed useful life was assumed to apply when equipment is used 180 days per season. To account for wear depreciation, plants operating at 180 days or less were assessed a lower depreciation rate proportionate to the days per season operated, and plants operating at more than 180 days per season were given higher depreciation rates. Costs and expected life of equipment are given in Appendix A, Table 3. For the building, a straight line depreciation was determined on a 30-year expected life.

Repair and maintenance of equipment were assessed at a combination of a fixed and a variable rate, the latter being conditioned by the number of hours of operation. The rates differed also depending upon the complexity of the equipment. A given piece of equipment was judged as complex (having many parts) or non-complex, (having few parts). For the non-complex, a charge was levied at 1% of replacement cost plus 0.13% of replacement cost per 100 hours of use, while the complex were charged at 2% of replacement cost plus 0.20% of cost/100 hours use. Repair and maintenance of the building were charged at 1% of the building cost.

Interest charges were assessed at 6 percent of replacement costs as a figure representative of charges for agricultural loans.

Taxes in Northern Maine have recently been in the vicinity of 32 mills on full evaluation. For the analysis, taxes were assessed at 3.2% of replacement costs.

Insurance rates for a particular concern are dependent upon many factors including location, structural material, class rating of the municipal fire department, etc. To be representative of a metal building, off-the-farm, without a sprinkler system but within 3 miles of a fire station, an assessment of $1.05 per $1,000 valuation was selected as the base insurance rate for the building. The assessment was increased as building size increased, at the rate of 1% for each 1,000 sq. ft., or portion thereof in excess of 5,000 sq. ft. Rate for equipment insurance was determined by multiplying the building insurance rate by 0.9 and adding 60 cents—a formula in use in the Northern Maine area.

Packing Materials and Charges

Containers and closures for the packaged product are assessed at prices in effect during the spring of 1975, and are given in Appendix A, Table 6. Miscellaneous supplies, which include carlining paper, light bulbs, staples and staplers, etc., were assessed at a rate of 2¢ per cwt. of output. Handling of off-grade potatoes (undersize and culled potatoes) was assessed at 10.3 cents per cwt of off-grade. An industry tax was assessed at 0.61¢ per cwt of output.

It was assumed that all packaged product was Federal-State inspected. A charge of 5 cents per cwt output was assessed unless the output reached a level where the sum of the unit cost equalled the charge of employing an inspector on a contract basis for a 40-hour week ($300), or 6,178 cwt output per week (1974-1975 level of charges).

It was further assumed that the practical maximum rate for one inspector, taking a 0.5% sample of the output, would be 400 cwt output per hour. At output rates over 400 cwt/hr two inspectors would be employed.

Manager, Foreman, Mechanic, and Packing Labor

Each packing operation is assumed to have a manager. Should the manager work as part of the packing crew, ½ of his wages is assumed to apply to management and the other ½ to labor. For this analysis, it was assumed the manager did not perform as part of the packing crew. Where the supply rate was 300 cwt/hr or less, the manager was assumed to receive a salary which equals twice the wage rate of a member of the packing crew. At supply rates in excess of 300 cwt/hr, an additional 6¢ for each cwt/hr of input in excess of 300 was assessed, conditioned by the length of the packing season: e.g., at 90 days of operation, the rate would be 4¢; at 180 days, 6¢; and at 240 days, 8¢. This procedure increases the manager's salary as his responsibilities increase with the size and volume of the packing operation.

A crew foreman was assumed in plants exceeding a 100 cwt/hr input rate. His salary was assumed at 1.5 times the packing labor wage rate, plus an additional 4¢ for each cwt/hr input, assessed similarly to that of the manager.

A mechanic was assumed in plants that had a supply rate greater than 200 cwt/hr and a total seasonal input volume of 200,000 cwt or more. The salary for the mechanic was assumed the same as the foreman, except 2¢ for each cwt/hr input was used.

The wage rate for packing labor was assessed on an hourly basis, straight time. To this was added 5.85% for Social Security, 3.94% for Workman Compensation, and 2.0% for the Unemployment Compensation contribution. A wage of $2.75 per hour was assumed. The working day was considered to be 9 hours, and the average operating time was set at 80% with the remaining time assumed utilized in such activities as change of supply source, changing of bag size, mechanical breakdown, change of loading vehicle, etc.

Office and Administrative Charges

For packing operations handling less than 400 cwt/hr it was assumed no secretary was employed, but that this aspect of the business was covered by the manager. When handling rates were greater than 400 cwt/hr, employment of a secretary is assumed for the number of days the plant is in operation at the rate of $18.40 per day plus payroll taxes and contributions. Other charges in this category, such as telephone, office supplies, licenses, accounting charges, etc., were assessed at a constant unit rate, with the levels based upon case studies.

RESULTS

It should be emphasized that practical maximum supply rates for packing lines, and the unit costs of packing as they are given in this section were determined assuming a specific quality of potatoes being supplied. It was assumed that 10 percent of the supply would be removed as undersize tubers and 10 percent of the supply would be removed by sorters as grade defective. Although both maximum rates and unit costs may change with a different quality of product handled, the relationship of the packing lines one to another and the effect of scale of operation would remain essentially the same.

Equipment Selection for Packing 10-lb Bags

For packing 10-lb bags with standard settings for all variables excepting supply rate, the POPACK I program produced 45 combinations of equipment and labor for handling the flow of potatoes as input rates were increased from 80 to 800 cwt/hr. However, by utilizing the POPACK II program and determining when capital-labor substitution in the bagging area yielded lower unit costs, 38 combinations resulted as the least-cost combinations when packing in 10-lb bags. The least-cost curve indicates the many breaks as the stated practical maximum of one or more of the input items is reached. The change, such as to a different capacity piece of equipment, the number of laborers in the crew, or the packing building size results in a change in unit cost of output (Figure 3).

Ten specific supply rates produced the maximum practical flow rate for the three-piece equipment combination of washer-dryer, sorting table, and spool sizer. These lines were established as the model lines for further comparison, and maximum input rates were 175, 263, 352, 427, 440, 526, 615, 665, 792, and 800 cwt/hr. (These will be subsequently referred to, in order, as Line 1, Line 2, Line 3, . . . , Line 10.) These rates were established with variables at "standard values" (Appendix A, Table 1.), and would be different if, for example, the undersize and/or off grade proportions were changed. Within the ten model packing lines, there were changes in the area of water supply, in the size of the bulk scoop supply system, the bagging equipment, and the number of workers needed to bale the 10-lb bags in master con-

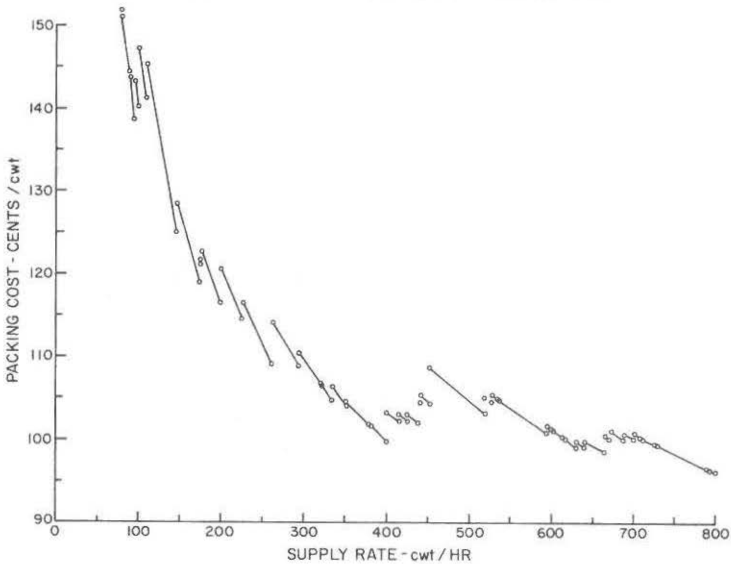


Figure 3. Least cost curve when packing potatoes in 10-lb. bags, with variables at Standard Setting. Standard Setting of variables is given in Appendix A, Table 1.

tainers or to load the transporting vehicle in order to retain a least-cost setup. At one point (518 hundredweight per hour input), an additional Federal-State inspector was required to handle the output. Beginning with Line 5, the flow rate exceeded the capacity of single-line setup, and two of certain pieces of grading equipment were required to accommodate the flow rates. For Lines 6 through 9, two units of all pieces of grading equipment were needed except for a chain sizer. Line 10 is essentially two setups of Line 4 with a common supply system. (See Appendix B).

A major upward shift in the level of unit cost occurred between supply rates of 400 and 453 cwt/hr. Affecting this change not only were changes in requirements for the size of the packing building, the packing line equipment, and the packing line personnel, but also the addition of a secretary and an additional unassigned worker to the total operation. (See section on Assumptions and Special Occasion.) This resulted in unit costs at input rates above 400 cwt/hr being as high or higher than at the 400 cwt/hr level until the supply rate was nearly doubled. (See Figure 3).

Least-cost per unit decreased rapidly between input rates of 80 and 175 cwt/hr, dropping from about \$1.52 to \$1.19 per cwt at 175 cwt/hr which is the practical maximum rate that can be handled by Line 1. Unit costs then decreased by about \$.25 per cwt between inputs of 176 and 800 cwt/hr.

Standard Analysis

To analyze the cost of packing a mixture of bag sizes, it has been assumed that the line most efficient when packing the predominant bag-size would be used, which for Maine, was found to be the 10-lb bag. The various selections of equipment and personnel obtained by previous analysis for Line 1 through Line 10 when packing 10-lb bags only were introduced as standards in the POPACK II program. Likewise, least-cost equipment for bagging 50-lb bags was determined and introduced also. For the standard analysis, all variables, except supply rates, were held constant as indicated in Appendix A, Table 1. For each of the ten model lines, the maximum and lesser supply rates (when packing 10-lb bags) were introduced, with no change in the assigned equipment or labor, to obtain a cost curve for each line (Figure 4). The proportion of time spent packing each of the four bag sizes was established so that the output would result with approximately 7% in 5-lb bags, 42% in 10-lb bags, 15% in 20-lb bags, and 36% in 50-lb bags.

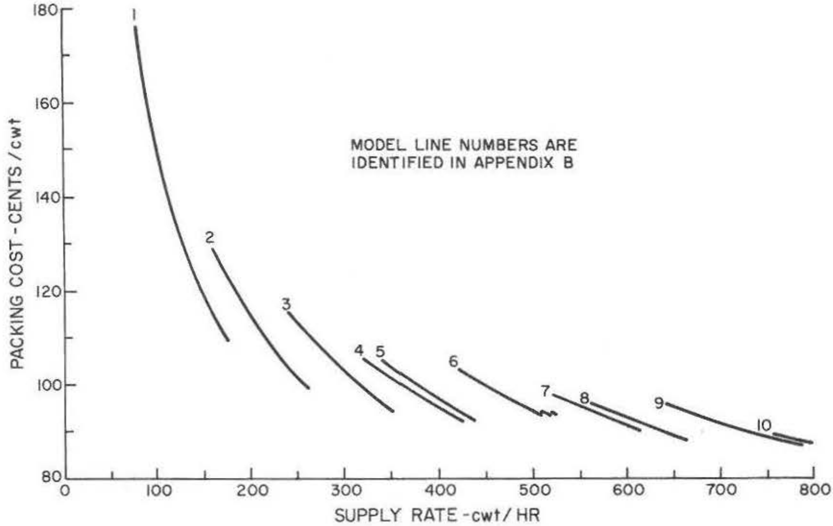


Figure 4. Cost curves for ten potato packing lines, with variables at Standard Setting. Standard Setting of variables is given in Appendix A, Table 1.

It should be noted that if the stated input rate cannot be maintained while 5-lb bags are being packed, the maximum input rate possible under the prescribed conditions is determined by the computer program. The lower rate is used while analyzing packing of the 5-lb bags, with the analysis returning to the stated input rate for the analysis of the other bag sizes. This feature affects the total seasonal output of the model line, and, therefore, the unit costs, because a season has been defined as a certain number of working days.

The cost per cwt of output was $1.76, $1.28, $1.14, and $.90 for 5-, 10-, 20-, and 50-lb bags, respectively, and $.74 for Chefs Special, for a weighted average cost of $1.10 per cwt when the supply for Line 1 was at 175 cwt/hr. Corresponding costs for each Line at the maximum supply rate are given in Table 3. For purposes of comparison, reference will be made to the weighted average cost figures in the remainder of this report.

Table 3

Unit Cost Prorated to Size of Container with Variables at Standard Settings, at Maximum Practical Capacity for Ten Potato Grading and Packing Lines

Line	Input rate	Cost per hundredweight					
		5-lb bags	10-lb bags	20-lb bags	50-lb bags	Chef's Spec.	Total Pkgd[1]
	cwt/hr	Dollars					
1	175	1.76	1.28	1.14	.90	.74	1.0981
2	263	1.44	1.18	1.05	.80	.63	.9909
3	352	1.49	1.12	.99	.74	.67	.9455
4	427	1.52	1.10	.97	.72	.63	.9241
5	440	1.53	1.10	.96	.72	.64	.9233
6	526	1.42	1.13	1.00	.75	.61	.9433
7	615	1.41	1.09	.96	.71	.57	.9067
8	665	1.39	1.07	.94	.69	.55	.8865
9	792	1.38	1.06	.93	.68	.52	.8702
10	800	1.38	1.06	.92	.68	.52	.8677

[1] Product mix for 5-, 10-, 20-, and 50-lb bags is 7, 42, 15, and 36 percent, respectively.

Unit costs, when lines are operated at their maximum practical capacity, decrease as the size and capacity of the line is increased until a supply rate of 440 cwt/hr is reached with Line 5. The termination point of the next higher capacity equipment (Line 6 at 526 cwt/hr input) is higher than at Line 5 primarily because a second full time Federal-State inspector is required to inspect the maximum output of Line 6. The remaining four lines again demonstrate a decrease in cost per unit as maximum practical capacities are increased.

An envelope or long-run planning curve connecting the points of lowest unit cost for each of the ten lines may represent the cost relationship of scale under the standard analysis. (Figure 5) This curve is used, later in this report, for comparison of the changes in variable settings.

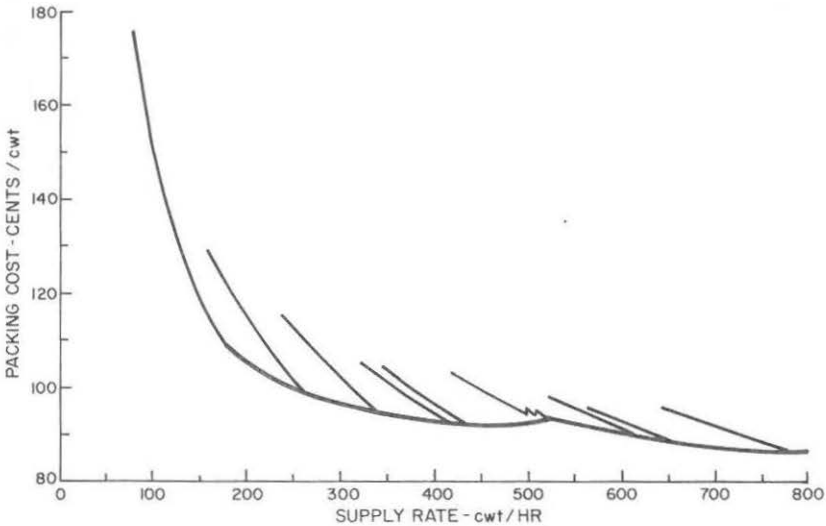


Figure 5. Envelope or Long Run Planning Curve representing costs of packing round-white potatoes.

Ownership and Operating Costs

A breakdown of the elements which make up the cost of packing potatoes shows that ownership costs for the packing building and the equipment constitute from 8 to 11 percent of the total, with operating costs accounting for the remainder. Among operating costs, containers and ties are the largest item, and account for 39 to nearly 50 percent of total costs. Since cost of containers and ties was obtained as a specified rate sheet, with no manifestation of volume discounts, the analysis indicates that this item constitutes about 43 cents per cwt packed regardless of volume (Table 4).

The analysis indicates that the reduction in unit costs as the capacity of the packing line is increased results primarily from a reduction of the unit cost of labor and management. Of the exhibited reduction of 33 cents per cwt (109.8 cents to 86.8 cents), 20 cents (45.7 to 25.7) is accounted for by the labor and management efficiences. About ½ of the decrease is noted between Lines 1 and 2, which includes the change from manual bagging of the product to semi-automatic bagging of the product. Some efficiencies are also noted in the Services and Supplies category which reflect scale in the pricing of utilities, and some reduction from full-time employment of Federal-State inspection rather than piece-rate payment for the service. At cost levels assumed for this report, unit cost of full-time employment of an inspector equals the unit cost by piece rate when input rates are about 178 cwt/hr.

Table 4

Distribution of Ownership and Operation Costs, Ten Packing Lines at Maximum Practical Capacity

	Supply rate in hundredweight per hour									
	175	263	352	427	440	526	615	665	792	800
	cents per hundredweight									
Packing Building	3.4	2.2	2.6	2.2	3.0	2.5	2.2	2.0	2.0	2.0
Equipment Overhead	5.5	7.8	6.5	6.3	6.2	7.4	7.2	6.8	6.6	6.6
Utilities	0.8	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5
Services & Supplies	11.6	10.7	9.7	9.2	9.1	10.5	10.0	9.7	9.2	9.2
Container & Ties	42.7	43.2	42.8	42.7	42.6	43.0	42.9	42.8	42.8	42.8
Payroll, including manager	45.7	34.5	32.3	31.5	30.7	30.3	27.9	26.7	25.9	25.7
Total	109.8	99.1	94.5	92.4	92.3	94.3	90.7	88.6	87.0	86.8

EFFECT OF CHANGE IN VARIABLES

Effect of Wage Rate

Hourly wage rates of $2.50, 3.00, and 3.25 were compared with the standard $2.75 per hour rate. Unit costs increase as the wage rate increases, and at 175 cwt/hr, a $.25/hr increase in wage rate resulted in an increase of slightly over 4 cents increase per cwt; at 800 cwt/hr, the increase was a 2¼ cents. (Figure 6)

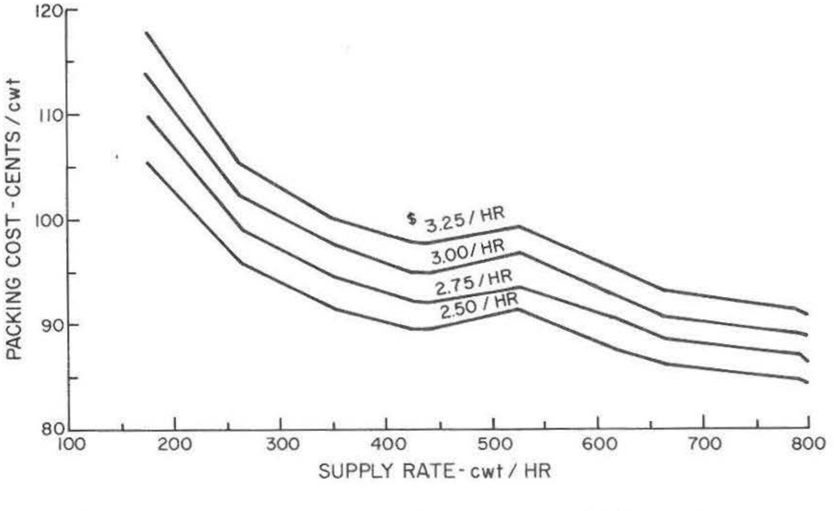


Figure 6. Effect of wage rate on costs of packing round-white potatoes.

Effect of Length of Operating Season

Fixed or overhead costs on a unit basis are reduced as the seasonal volume of product associated with these costs is increased. To illustrate the economic effect of the number of days of operation on packing lines of the various scales, the POPACK II program was utilized to analyze unit-costs at 120, 150, and 210 days of operation and these were compared with the standard data (180 days). All other variables were held constant. Envelope curves of the four lengths of season are compared (Figure 7), and show that, as compared to the standard, costs are increased about 4% when operating 120 days and 1 ⅔ % when operating 150 days, and are decreased about 1% when operating 210 days. Little if any difference occurs from these rates as the size of the operation increases. For example, to operate at 175 cwt/hr for a 210-day season reduces cost/cwt by 1 cent, while at 800 cwt/hr input, the reduction is about 1.1 per cwt. Increasing from a 120-day season to a 150-day season lowers cost about 2.2 cents/cwt, from 150-day to 180-day season reduces cost about 1.5 cents/cwt, and from 180-day to 210-day season shows about a 1.0 cents/cwt reduction.

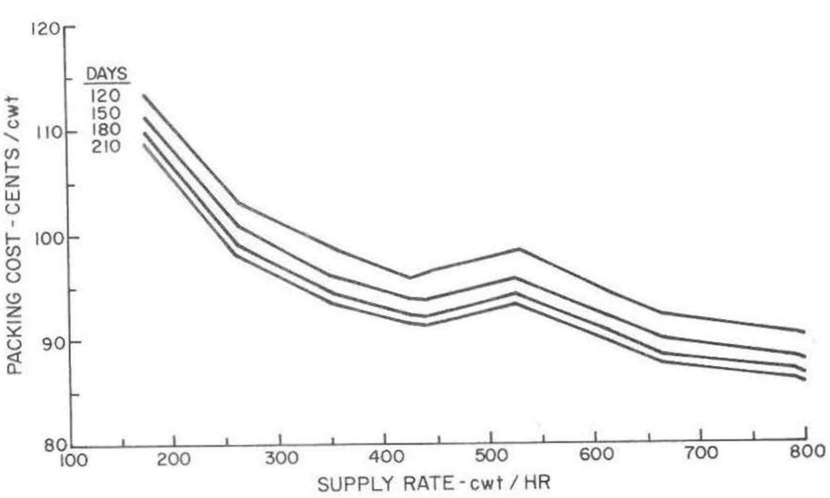


Figure 7. Effect of length of operating season on costs of packing round-white potatoes.

Effect of Operating Time as Proportion of Total Time

The proportion of overall time that equipment is operating also influences volume and associated costs. Operating times of 70% and 90% were compared with the standard 80%. At the 175 cwt/hr input rate, the 10 percent decrease in operating time resulted in a 7 percent increase in unit cost (nearly 8 cents), while at a 10 percent increase in operating time, from 80 to 90 percent, the decrease in unit cost was about 5½ percent (about 6 cents). At 800 cwt/hr, corresponding changes resulted in about 5¼ cents more and 4 cents less per cwt (Figure 8).

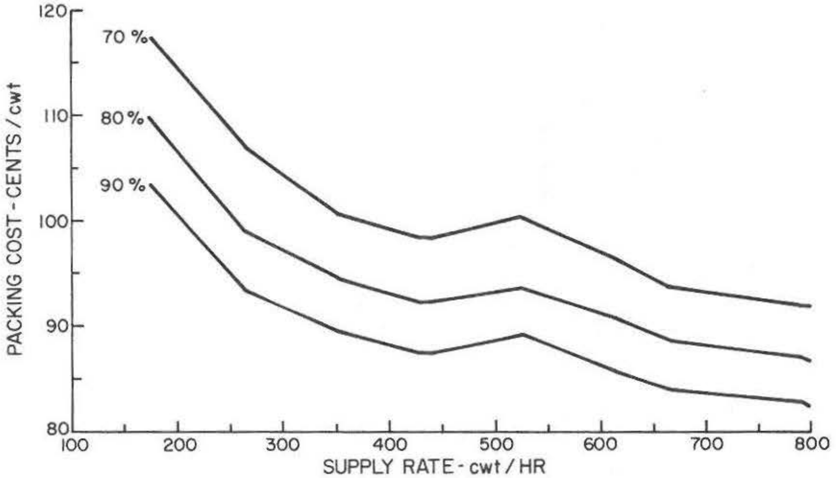


Figure 8. Effect of operating time as a proportion of total time on costs of packing round-white potatoes.

Effect of Quality of Input

The computer programs developed for analyzing the effect of scale of operation in potato packing (POPACK I and POPACK II) might be used to analyze in detail the effect of the quality of the input on unit costs. Such an analysis is beyond the objectives of this study. Changes in proportion undersize change the flow rate presented to the washer-dryer and the sorters. Changes in proportion grade defective change the flow rate that can be inspected and sorted by a given number of sorters and thus the flow rate to the bagger. Changes in quality can and do influence which step in the process becomes the bottleneck in any specified equipment-labor combination. Changes in quality can and do influence the input rate possible, as well as the unit cost of the packaged product.

As an example, Line I includes a 24-inch washer-dryer, two sorters, and three crew members at a 2-head manually operated bagger. The maximum practical capacity of a 24-inch washer-dryer is 158 cwt/hr.

With 10 percent of the input removed by sizing, 158 divided by .90 yielded 175 cwt/hr as a maximum supply rate with this quality of stock. If none of the supply to the line were removed by the sizing process, the maximum supply rate would be 158 cwt/hr with this quality of stock.

With 158 cwt/hr as a maximum passing through the washer-dryer to the sorting table, the maximum grade defective that could be removed from the flow by the two sorters is about 14 percent of the 158 cwt/hr or about 22 cwt/hr (see Appendix A, Table 4 or Figure 2). A quantity, 16 cwt/hr or about 10 percent, must be removed from the sorting table if the flow is not to exceed the 122 cwt/hr maximum rate for the bagging arrangement, or 86 percent of the flow past the sorters (14 percent of the graded product was assumed to be removed and packaged as Chef's Special). Therefore, when the maximum flow through the washer-dryer exceeds 14 percent to be removed, the sorting becomes the bottleneck, and if it is less than 10 percent, the bagging arrangement becomes the bottleneck. Only when the percentage of the flow to be removed is betwen 10 and 14 percent is the washer-dryer the bottleneck.

A general statement can be made that quality of input has a negative effect on unit costs of packaged product. The higher the quality of the input, the lower is the unit cost of packing. Figure 9 indicates the

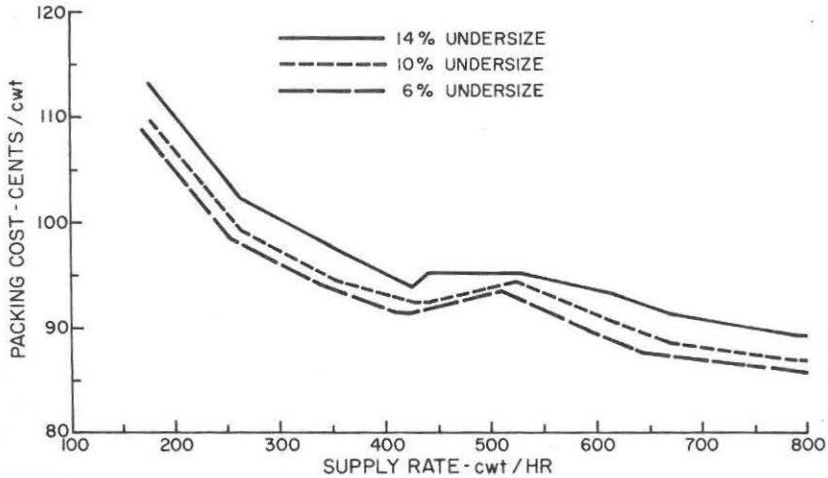


Figure 9. Effect of proportion undersize tubers on costs of packing round-white potatoes.

decrease in unit cost of output as quality increases with the lowering of the proportion undersize from 14 to 10 to 6 percent, when grade defective is held constant. Figure 10 indicates the decrease in unit cost

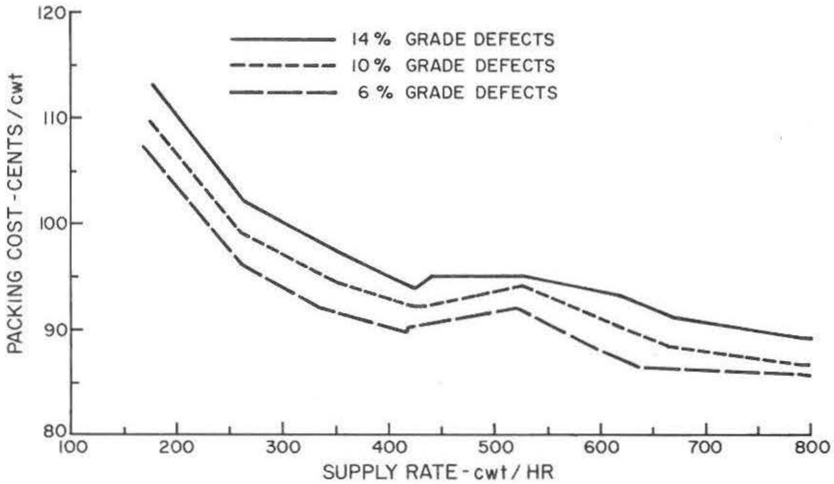


Figure 10. Effect of proportion grade defective on costs of packing round-white potatoes.

of output as quality increases with the lowering of the proportion grade defective from 14 to 10 to 6 percent, when undersize is held constant. In both Figures 9 and 10, it may be noted that the maximum input rate for several of the lines is reduced when either undersize or grade defects are at six percent, indicating that the sorting or the bagging sections of the line have become the bottleneck rather than the washer-dryer in this particular combination of equipment and labor.

No notable or consistent difference is noted in the degree to which quality changes influence unit costs as capacities or scale of the operation are increased.

Effect of Size of Container Packed

Unit cost of output differs depending upon the size of the container packed, and, therefore, on the proportion of the total packed in each container size. An indication of the difference is given in Table 3 where the unit costs under the Standard Analysis are displayed. To further illustrate the effect, each line was analyzed when packing in 5-lb bags and when in 20-lb bags, and comparison made to packing in 10-lb bags (all with Chef's Special packed also), but with no 50-lb bagging equipment involved (Figure 11). The results indicated that while the differential in the cost of packing in 20-lb bags was 16 to 18 cents lower than in 10-lb bags, the differential between 10-lb bags and 5-lb bags was not consistent. In lines 1 through line 6, the differential ranged from about 19 to 40 cents. For line 7 through line 10, the differential was about 24 cents. This variability in 5-lb container costs is a reflection of the type and capacity of the bagger. All comparisons for bag size were analyzed with equipment which had been chosen as most efficient when packing 10-lb bags.

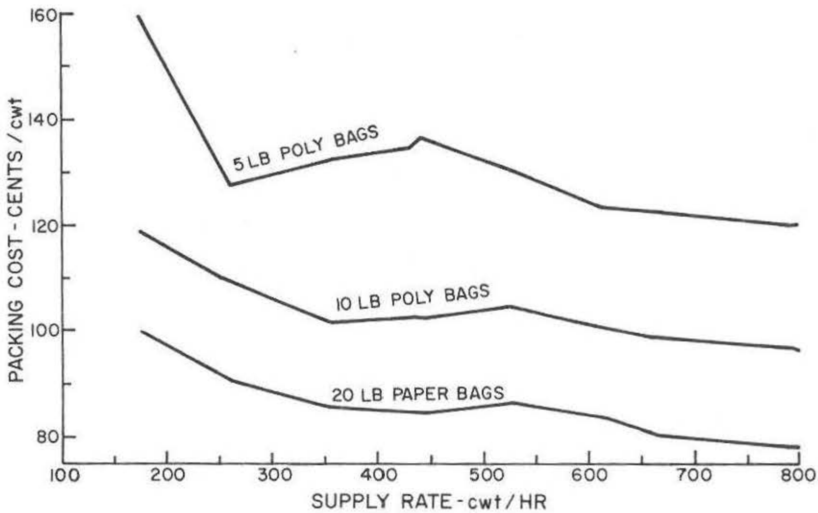


Figure 11. Relationship of cost of packing round-white potatoes in three sizes of containers.

SUMMARY AND CONCLUSIONS

The Maine tablestock potato industry is characterized by a large number of small packing operations, most of which pack no more than one truckload per day nor more than 30 truckloads per season, and most of which are located "on the farm" and have no railroad facilities. The greatest volume of Maine tablestock potatoes is round-white varieties marketed in 10-pound bags. Packing operations, of the above nature, are generally not equipped with the labor force or equipment necessary to efficiently package potatoes in small, consumer-size packs.

A shift in the Maine tablestock potato industry to fewer and larger packing operations would result in a lower cost to the industry through advantages of economies of scale, through efficiencies from specialization and from volume of business. Greater quality control could result from fewer and larger packing facilities, and the overall reputation of the fresh potato from Maine could be enhanced. These factors are instrumental in Maine's challenge to remain competitive in the tablestock market. Cost as included in this study reflects in-plant efficiency, however, and does not take into consideration improvements in distribution efficiency or in quality of product.

The objective of this study was to find where economies in scale lie, and what, if any, would be the preferred or most economical in packing facilities. Data relative to equipment and labor requirements and capabilities and to materials and services were obtained through manufacturers, sales agencies, research studies and case studies. Two computerized programs were developed to select equipment, labor, and facilities which would be most efficient and least-cost and this was done for packing 10-pound bags with potatoes. Ten model lines resulted from the analysis allowing for input rates of 80 to 800 cwt/hr when based on a particular set of variables established as "standard". Among the standard variables were 180 working days of 9 hours each, with the equipment operating 80% of the time handling an input flow of potatoes from which 10 percent were removed as undersized and 10 percent were removed as grade defective.

The product mix was apportioned to result in 7, 42, 15, and 36 percent in 5-lb poly, 10-lb poly, 20-lb paper, and 50-lb paper bags, respectively, with 14% of the graded product being simultaneously bagged in 50-lb bags as Chef's Special.

For each of the 10 model lines, unit costs increased as the input rate was lowered from the practical maximum capacity of the specified line. As lines increased in practical maximum capacity, unit cost was reduced until an input of 440 cwt/hr was reached. Increased costs because of additional clerical and service personnel resulted in an increase in unit costs before a decrease again occurred as larger capacity lines were considered.

Several variables influence the resulting unit cost of packing potatoes. Of those analyzed, unit costs are increased as wage rate is increased, as operating time as a proportion of overall time is decreased, and as the size of the container packed is decreased. Unit costs are decreased as length of the packing season is increased, and as the quality of the input to the packing line is raised.

The nature of the cost structure, under practices and principles used in this analysis, indicate that caution should be used in planning of tablestock packing facilities which exceed a maximum practical capacity of about 440 cwt/hr input. Lower unit costs can be obtained with higher capacity operations, but this should be weighted against the increase in management required, the ability to continuously market the output capable in such an operation, and the ability to maintain supply to operate continuously at the higher rates.

Economies are obtained due to scale. However, economies are primarily obtained by operating the packing line, regardless of its capacity, as near to the full capacity as possible, for as great a portion of the working day as possible, with as good quality of raw product as possible. Efficiency is not limited to large packing operations but is within the reach of small firms as well.

LITERATURE CITED

1. King, F. Richard, Winston W. Grant, and Edward S. Micka. *Optimum Number, Size and Location of Tablestock Potato Packing Plants in Maine,* Maine LSA Exp. Sta. Bull. 697, Sept. 1972.

2. Johnston, Edward F., *Maine Potato Storage and Tablestock Packing Facilities - 1976,* in process.

3. Johnston, Edward F., and N. H. Pelsue, Jr. *Marketing Characteristics in Shipments of Maine Tablestock Potatoes,* Maine LSA Exp. Sta. Misc. Report Nos. 163 and 172.

4. Orr, Paul H., "Powered Buck Scooping in Potato Storages," MRR No. 916, USDA, ARS, 1971.

APPENDIX A

Table 1. Standard Settings for Variables

Days of operation	180 days
Hours per day	9 hours
Operating time	80%
Undersize potatoes	10%
Off-grade removed	10%
Graded product:	
U.S. No. 1, 3¼ in. maximum	86%
Maine grade Chef's Special	14%
Wage rate	$2.75 per hour (straight time)
Payroll taxes, etc.	11.79%
Percent of operating time:	
when packing 5-lb bags	11%
" " 10- " "	41%
" " 20- " "	14%
" " 50- " "	34%
Container prices	1975 level
Container type (5- and 10-lb)	Film (poly)
Net weight of containers:	
5-lb	5.3 lbs
10-lb	10.4 lbs
20-lb	20.7 lbs
50-lb	50.9 lbs
Portion of bags broken or lost	2%
Utility charges	sliding scale, 1975 levels
Equipment prices	1974-75 level
Overhead costs:	
Depreciation	straight line
Insurance	1.545 %
Repair and maintenance	1.0 or 2.0%, plus usage
Taxes	2.4%
Interest charge	6%
All office items	18.91 cents/cwt packed

Table 2. Supply Systems Related to Supply Rate and Size of Storage

Range of Supply Rate	Size of Storage	Distance Required	Supply System	
	(Capacity in cwt)	(one way)	(Scoop size)	(Hopper size)
80 cwt/hr or less	23,640	92 feet	165# cap. scoop	25 cwt
81 to 100	42,000	124 "	330 " "	50 cwt
101 to 200	60,000	156 "	495 " "	50 cwt
201 to 400	120,000	200 "	1000 " " 20′ conveyor	100 cwt
401 to 600	240,000	200 "	1.5 times cost of 1000 #setup	–
601 to 800	386,000	267 "	2 times cost of 1000 #setup	–

Table 3. Specifications of Potato Handling and Packing Equipment

Size	Life	Horsepower Requirement	Repair Rate Code[1]	Replace-ment Cost	Associated Labor	Maximum Practical Capacity
	Supply System (Bulk scoop, hopper, conveyors if used)					
	Years	Horsepower	Index	Dollars	Number	Cwt./hr.
1. 165-lb. cap. bucket	10	.75	1	3,565	1	80
2. 330-lb. cap. bucket	10	.75	1	4,805	1	100
3. 495-lb. cap. bucket	10	.75	1	5,510	1	200
4. 660-lb. cap. bucket	10	1.00	1	10,510	1	263
5. 825-lb. cap. bucket	10	1.00	1	11,725	1	320
6. 1000-lb. cap. bucket	10	1.00	1	12,400	1	380
7. 1000-lb. cap. bucket plus 20′ conveyor	10	1.75	1	13,100	1	400
	Chain (or Screen) Sizer (Operated at 45′/min)					
1. 24″ width	15	.50	0	1,830	.5	324
2. 36″	15	.50	0	2,580	.5	486
3. 48″	15	.50	0	3,540	.5	648
4. 60″	15	.50	0	4,665	.5	810
	Washer - Dryer					
1. 24″ width	10	.75	1	2,915	0	158
2. 36″	10	1.00	1	3,400	0	237
3. 48″	10	1.50	1	4,120	0	317
4. 60″	10	1.50	1	5,300	0	396
	Roller Sorting Table (at 30 ft./min. forward speed)					
1. 24″ width	10	.75	0	1,040	2	214
2. 30″	10	1.00	0	1,470	3	270
3. 18″ + 18″	10	1.50	0	2,895	4	324
4. 22″ + 22″	10	1.50	0	3,345	4	385
	Rubber Spool Sizer					
1. 24″ width	10	.75	1	1,375	0	224
2. 30″	10	.75	1	1,475	0	280
3. 42″	10	1.00	1	1,755	0	390
4. 48″	10	1.00	1	1,910	0	448

Table 3. (continued)

Size	Life	Horsepower Requirement	Repair Rate Code[1]	Replacement Cost	Associated Labor	Maximum Practical Capacity
	Years	Horsepower	Index	Dollars	Number	Cwt./hr.
Belt Distribution Conveyors at 45′ per min.						
1. 24″ width (@ 8′)	15	.25	0	509	0	456
2. 30″ (@ 10′)	15	.50	0	540	0	570
3. 36″ (@ 10′)	15	.50	0	610	0	684
4. 36″ (@ 12′)	15	.50	0	695	0	684
5. 42″ (@ 12′)	15	.50	0	765	0	792
Bagging Equipment for 50-lb. bags (includes closing, tying, and weighing equipment)						
1. 2 head manual	15	.50	0	5470	5 (max)	238
2. Semi-auto. rotary	8	2.50	1	14430	1	300
Bagging Equipment for 5-, 10-, 20-lb. bags (includes closing, tying, and weighing equipment)						
						5# 10# 20#
1. 2 head manual	10	.50	1	7310	7 (max)	127 200 221
2. 10 head rotary	10	.50	1	18505	3	107 187 205
3. 14 head rotary	8	1.50	1	24650	4	147 250 273
4. 16 head rotary	8	2.25	1	29285	5	179 312 341
5. with auto hanger	8	2.58	1	31860	3	179 312 341
6. with auto hanger & tier	8	2.92	1	33570	2	179 312 341
Baling Equipment						
						5# poly 10# poly 10# paper
1. 1 baling unit	15	.83	0	4070	5 (max)	300 467 510
2. 2 baling units	15	1.67	0	8135	10 (max)	600 930 1020
Conveyors						
1. 16′ long, 16″ belt	15	.50	0	445		
2. 20′ long, 16″ belt	15	.50	0	525		

[1] Code 0 = 1% of replacement cost plus .13% of replacement per 100 hours of use
" " 1 = 2% of replacement cost plus .20% of replacement per 100 hours of use

Table 4. Maximum Practical Capacity of Packing Line Labor

Grading

(inspecting and sorting to meet requirements of Grade)

Number in sorting crew[1]	Flow rate to sorting table when percentage to be removed from flow is[2]:					
	5%	10%	15%	20%	25%	30%
	cwt per hour					
2	214	178	152	132	120	100
3	306	246	207	187	157	138
4	385	320	273	238	212	183

Bagging

(Filling, weighing, and closing bags; manually operated baggers[3])

Number in bagging crew	Flow rate to bagger[4] when bag size being filled is:			
	5 lb.	10 lb.	20 lb.	50 lb.
	cwt per hour[5]			
1	16	25	27	34
2	48	75	83	101
3	75	122	132	162
4	95	150	165	205
5	111	175	194	238
6	121	190	210	324
7	127	200	221	367

Baling

(Filling and closing master container bags; contents 5 10-lb, or 10 5-lb consumer bags)

Number in baling crew	Number of baling tables	Rate of baling when consumer bag size and type is:		
		5-lb. film	10-lb. film	10-lb. paper
		Bales per hour		
1	1	84	126	138
2	1	150	195	220
3	1	220	390	441
4	1	280	444	495
5	1	300	467	510
5	2	370	585	661
6	2	440	780	882
7	2	500	834	936
8	2	560	888	990
9	2	580	909	1005
10	2	600	930	1020
11	3	780	1278	1431
12	3	840	1332	1485
13	3	860	1353	1500
14	3	880	1374	1515
15	3	900	1395	1530

(Table 4 Con't.)

Loading

Number in Loading crew	Containers handled (Bales, 20-lb. bags, or 50-lb. bags)
	containers per hour
1	300
2	550
3	850
4	1100
5	1400
6	1650

[1] No fewer than 2 nor more than 4 are considered to inspect and cull potatoes from a single lane of flow.

[2] Practical maximum quantity that can be removed from the flow by 2 sorters is 30 cwt/hr; by 3 sorters, 40 cwt/hr; by 4 sorters, 55 cwt/hr.

[3] Common names for baggers are "peck-gate" and "stop-start".

[4] If Chef's Special size are not packed separately, bagging rate for 5-lb bags is reduced by 10 percent, and for 10-lb bags by 3 percent. No change in rate applies when bagging 20- or 50-lb bags.

[5] To translate to approximate bag-per-minute rate, divide cwt/hr by 3.20 if 5-lb bags, by 6.25 if 10-lb bags, by 12.40 if 20-lb bags or 30.6 if 50-lb bags.

Table 5. Charges for Electricity, LP Gas, and Water

Rates for Electricity

For the first	8 KWH or less per month	$2.30
For the next	92 KWH used per month, per KWH	.081
For the next	500 KWH used per month, per KWH	.055
For the next	1400 KWH used per month, per KWH	.033
For all over	2000 KWH used per month, per KWH	.025

Rates for LP Gas

Number of tanks	Price (excluding taxes)
2 - 10	$4.73
11 - 50	4.06
51 - 100	3.76
101 - 200	3.61
201 - 300	3.51
Bulk	$216.00/year + 44.1¢/gal excluding taxes

(Table 5 Con't.)

Cost for Water[1]

Quantity of Potatoes to be Washed	Depth of Well	Cost of Drilling Well, and Pumping Equipment
40 cwt/hr or less	100 ft.	$1585
41- 80cwt/hr	125	2350
81-160	150	3250
161-320	175	4325
321-480	200	5620
481-640	225	6750
641-800	250	7500

[1] Unit cost of washing potatoes determined from overhead cost of well and equipment divided by quantity of potatoes.

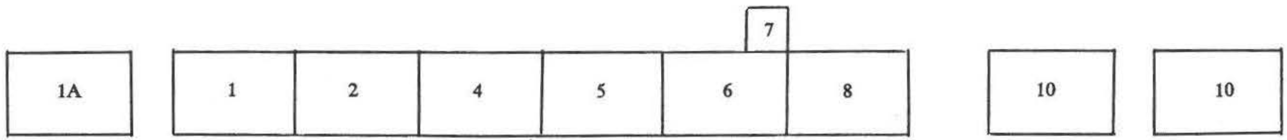
Table 6

Charges for Containers and Closures

Container	Price per 1000
	dollars
5-lb. poly	21.50
5-lb. paper	45.25
10-lb. poly	36.00
10-lb. paper	60.00
20-lb. paper	94.00
50-lb. paper	124.00
50-lb. paper, Chef's Special	124.00
Master Containers:	
for 5-lb. bags	145.00
for 10-lb. poly bag	139.00
for 10-lb. paper bags	135.00
Closures:	
Staples for poly bags (wire)	.28
	($.86 per lb)
Wire for small paper bags	1.65
	($.48 per lb)
Ties for large paper bags	2.95

APPENDIX B

Model Line No. 1
Grading and Packing Round-White Potatoes



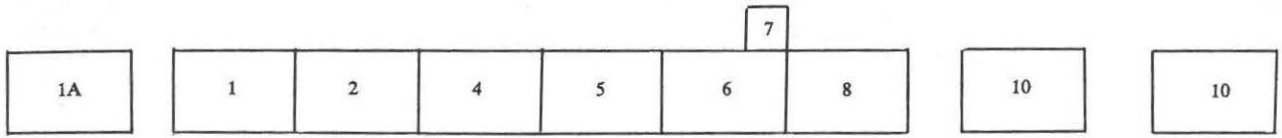
Packing Line Equipment

Code	Legend	Nature
1A	Bulk scoop	495-lb cap.
1	Hopper	50-cwt cap.
2	Chain sizer	24-in. wide
4	Washer-dryer	24-in. wide
5	Sorting table	24-in. wide
6	Spool sizer	24-in. wide
7	Oversize bagging	single head
8	Bagger with scales & closers	2-head manual
10	Baling table	rotary
11	Conveyors	2 @ 20 ft.
		1 @ 16 ft.

Labor when packing 10-lb. bags

Function	Workers
Supply	1
On-line	1
Sorting	2
Oversize	1
Bagging	3
Baling	3
Loading	1
Subtotal	12
Manager	1
Foreman	1
Mechanic	0
Office	0
Total	14

Model Line No. 2
Grading and Packing Round-White Potatoes



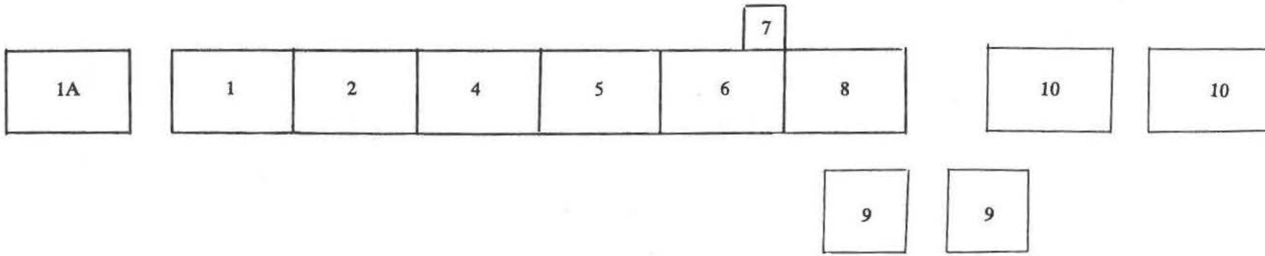
Packing Line Equipment

Code	Legend	Nature
1A	Bulk scoop	660-lb cap.
1	Hopper	75-cwt cap.
2	Chain sizer	24-in. wide
4	Washer-dryer	36-in. wide
5	Sorting table	30-in. wide
6	Spool sizer	30-in. wide
7	Oversize bagging	single head
8	Bagger	16-head rotary automatic hang and close
10	Baling table	rotary
11	Conveyors	2 @ 20 ft. 1 @ 16 ft.

Labor when packing 10-lb: bags

Function	Workers
Supply	1
On-line	1
Sorting	3
Oversize	1
Bagging	2
Baling	3
Loading	2
Subtotal	13
Manager	1
Foreman	1
Mechanic	1
Office	0
Total	16

Model Line No. 3
Grading and Packing Round-White Potatoes



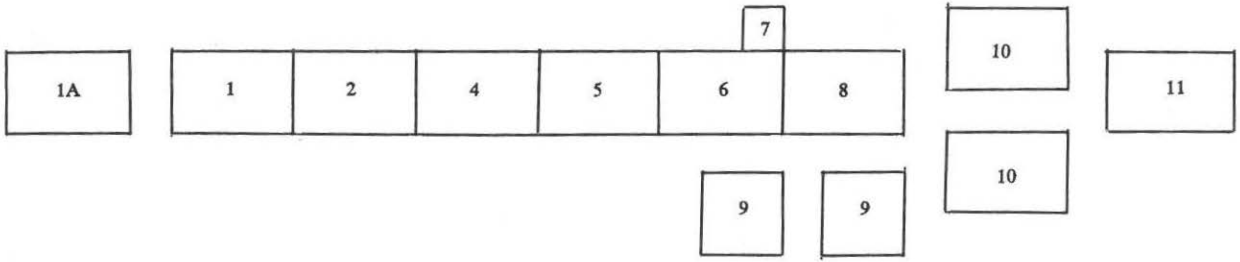
Packing Line Equipment

Code	Legend	Nature
1A	Bulk scoop	1000-lb cap.
1	Hopper	100-cwt cap.
2	Chain sizer	36-in. wide
4	Washer-dryer	48-in. wide
5	Sorting table	18 in. + 18 in. divided
6	Spool sizer	42-in. wide
7	Oversize bagger	single head
8	Bagger	16-head rotary auto hang and close
9	Bagger (50 lb)	2-head manual
10	Baling table	rotary
11	Conveyors	2 @ 20 ft. 2 @ 16 ft.

Labor when packing 10-lb. bags

Function	Workers
Supply	1
On-line	1
Sorting	4
Oversize	2
Bagging	2
Baling	5
Loading	2
Subtotal	17
Manager	1
Foreman	1
Mechanic	1
Office	0
Total	20

Model Line No. 4
Grading and Packing Round-White Potatoes



Packing Line Equipment

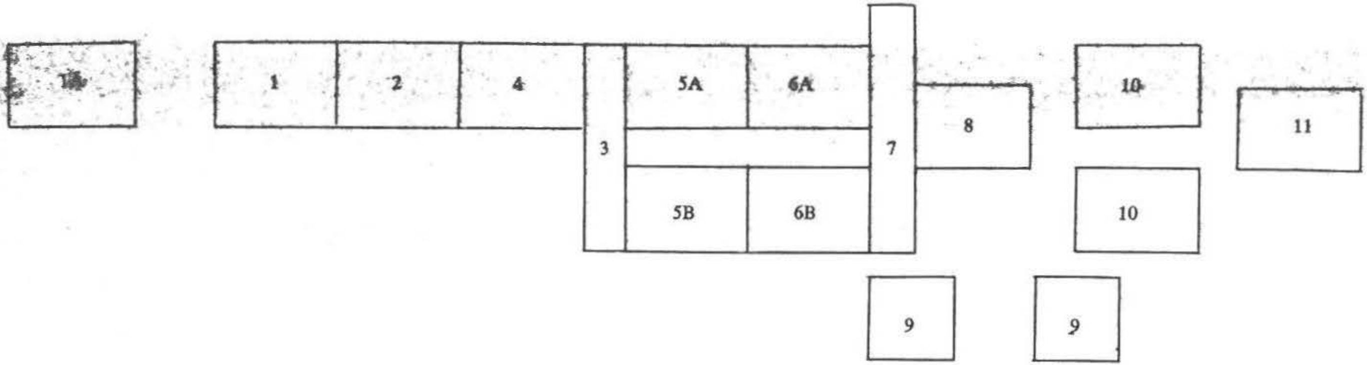
Code	Legend	Nature
1A	Supply system	*
1	Supply System	*
2	Chain sizer	36-in. wide
4	Washer-dryer	60-in. wide
5	Sorting table	22 in. + 22 in. divided
6	Spool sizer	48-in. wide
7	Oversize bagger	single head
8	Bagger	16-head rotary, auto hang and close
9	Bagger (50-lb)	2-head manual
10	Baling table	rotary
11	Conveyors	3 @ 20 ft. 2 @ 16 ft.

* One and ½ times cost and capacity of 1000-lb. capacity bulk scoop setup.

Labor when packing 10-lb. bags

Function	Workers
Supply	2
On-line	2
Sorting	4
Oversize	2
Bagging	2
Baling	5
Loading	3
Subtotal	20
Manager	1
Foreman	1
Mechanic	1
Office	1
Total	24

Model Line No. 5
Grading and Packing Round-White Potatoes



Packing Line Equipment

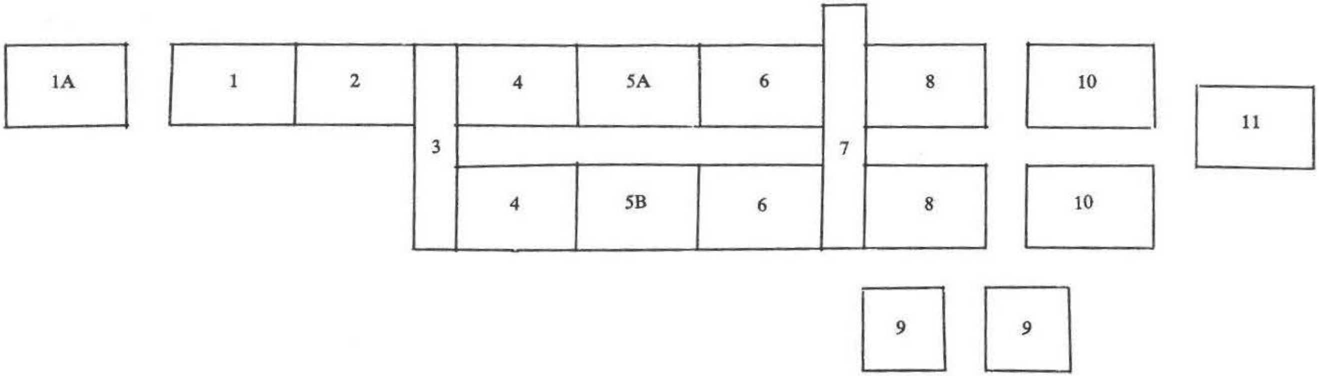
Code	Legend	Nature
1A	Supply system	*
1	Supply system	*
2	Chain sizer	36-in. wide
3	Distrib. Conveyor	24-in. wide
4	Washer-dryer	60-in. wide
5A	Sorting table	24-in. wide
5B	Sorting table	24-in. wide
6A	Spool sizer	24-in. wide
6B	Spool sizer	24-in. wide
7	Oversize bagging	2-head manual
8	Bagger	16-head rotary, auto hang and close
9	Bagger (50-lb)	2-head manual
10	Baling table	rotary
11	Conveyors	3 @ 20 ft. 2 @ 16 ft.

Labor when packing 10-lb. bags

Function	Workers
Supply	2
On-line	2
Sorting	4
Oversize	2
Bagging	2
Baling	5
Loading	3
	—
Subtotal	20
Manager	1
Foreman	1
Mechanic	1
Office	1
	—
Total	24

* One and ½ times cost and capacity of 1000-lb. capacity bulk scoop setup.

Model Line No. 6
Grading and Packing Round-White Potatoes



Packing Line Equipment

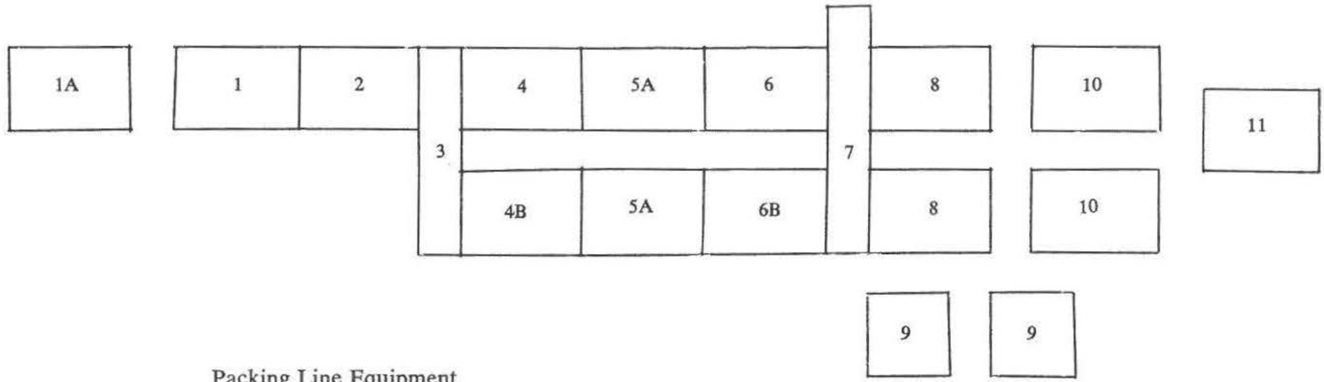
Code	Legend	Nature
1A	Supply system	*
1	Supply system	*
2	Chain sizer	48-in. wide
3	Distrib. conveyor	30-in. wide
4	Washer-dryer	36-in. wide
5A	Sorting table	30-in. wide
5B	Sorting table	24-in. wide
6	Spool sizer	30-in. wide
7	Oversize bagging	2-head manual
8	Bagger	16-head rotary, auto. hang and close
9	Bagger (50-lb)	2-head manual
10	Baling table	rotary
11	Conveyors	3 @ 20 ft. 2 @ 16 ft.

* One and ½ times cost and capacity of 1000-lb. capacity bulk scoop setup.

Labor when packing 10-lb. bags

Function	Workers
Supply	2
On-line	2
Sorting	6
Oversize	2
Bagging	4
Baling	6
Loading	3
Subtotal	25
Manager	1
Foreman	1
Mechanic	1
Office	1
Total	29

Model Line No. 7
Grading and Packing Round-White Potatoes



Packing Line Equipment

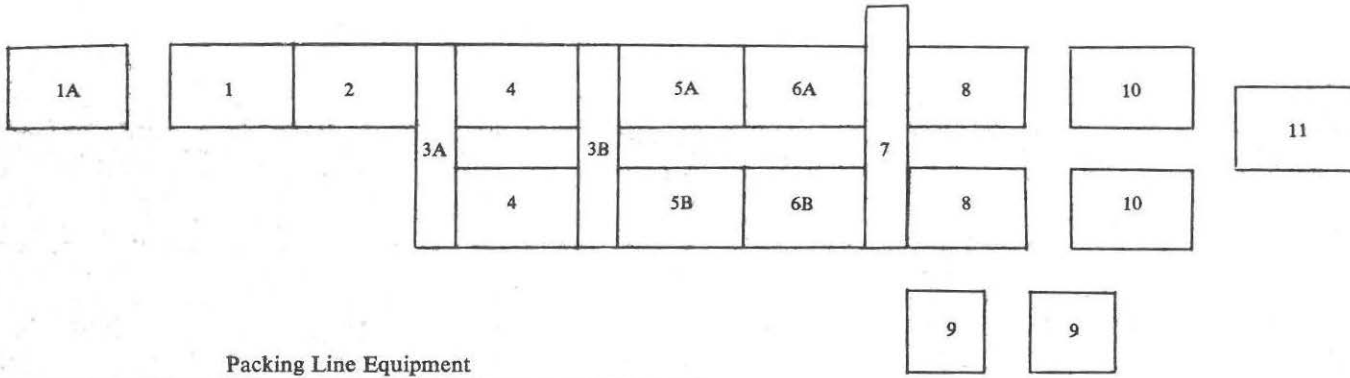
Code	Legend	Nature
1A	Supply system	**
1	Supply system	**
2	Chain sizer	48-in. wide
3	Distrib. conveyor	30-in. wide
4A	Washer-dryer	48-in. wide
4B	Washer-dryer	36-in. wide
5A	Sorting table	18 in. + 18 in. divided
5B	Sorting table	30-in. wide
6A	Spool sizer	42-in. wide
6B	Spool sizer	30-in. wide
7	Oversize bagging	2-head manual
8	Bagger	16-head rotary, auto hang and close
9	Bagger (50-lb)	2-head manual
10	Baling table	rotary
11	Conveyors	3 @ 20 ft.
		2 @ 16 ft.

** Twice cost and capacity of 1000-lb. capacity bulk scoop setup.

Labor when packing 10-lb. bags

Function	Workers
Supply	2
On-line	1
Sorting	7
Oversize	2
Bagging	4
Baling	7
Loading	3
	—
Subtotal	26
Manager	1
Foreman	1
Mechanic	1
Office	1
	—
Total	30

Model Line No. 8
Grading and Packing Round-White Potatoes



Packing Line Equipment

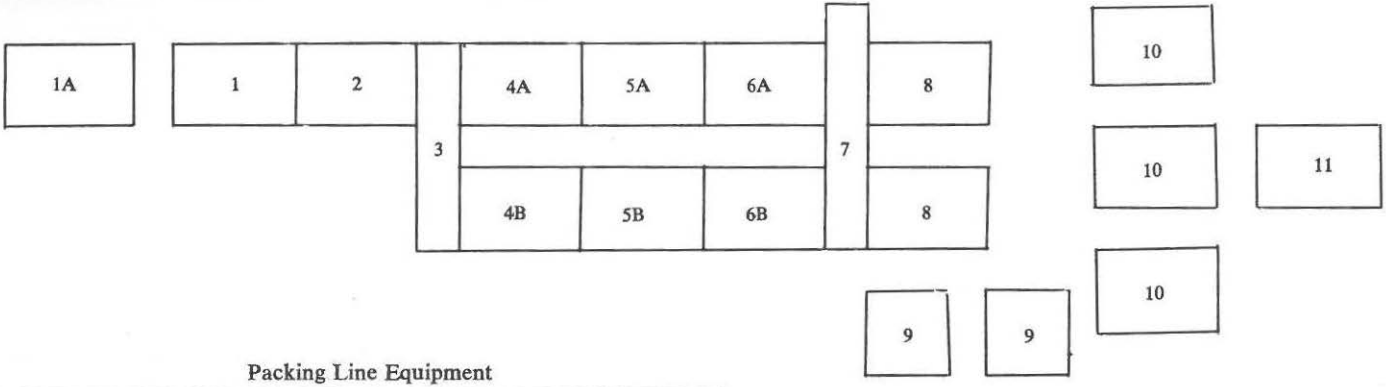
Code	Legend	Nature
1A	Supply system	**
1	Supply system	**
2	Chain sizer	60-in. wide
3A	Distrib. conveyor	36-in. wide
3B	Distrib. conveyor	30-in. wide
4	Washer-dryer	48-in. wide
5A	Sorting table	22 in. + 22 in. divided
5B	Sorting table	24-in. wide
6A	Spool sizer	48-in. wide
6B	Spool sizer	24-in. wide
7	Oversize bagging	2-head manual
8	Bagger	16-head rotary, auto hang and close
9	Bagger (50-lb)	2-head manual
10	Baling table	rotary
11	Conveyors	4 @ 20 ft. 3 @ 16 ft.

** Twice cost and capacity of 1000-lb. capacity bulk scoop setup.

Labor when packing 10-lb. bags

Function	Workers
Supply	2
On-line	2
Sorting	6
Oversize	2
Bagging	4
Baling	8
Loading	4
Subtotal	28
Manager	1
Foreman	1
Mechanic	1
Office	1
Total	32

Model Line No. 9
Grading and Packing Round-White Potatoes



Packing Line Equipment

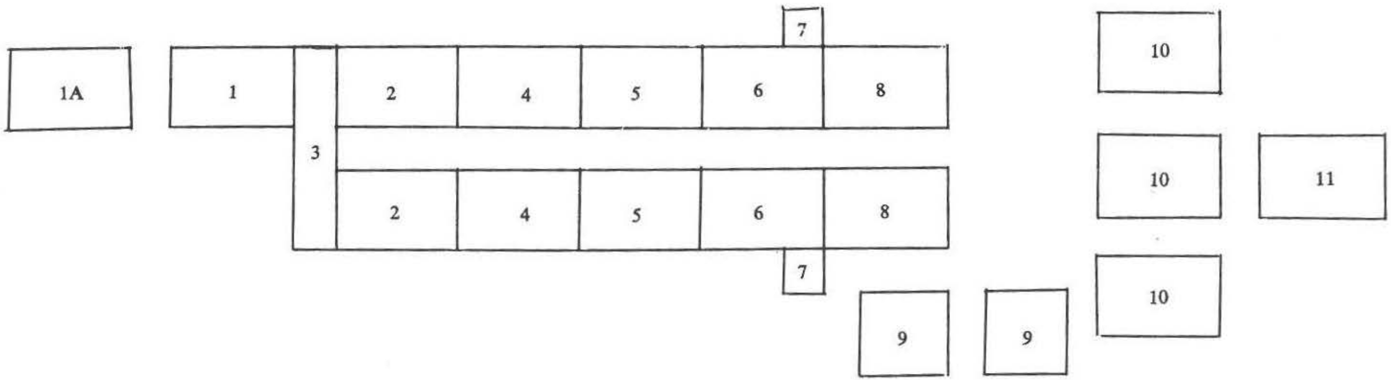
Code	Legend	Nature
1A	Supply system	**
1	Supply system	**
2	Chain sizer	60-in. wide
3	Distrib. conveyor	42-in. wide
4A	Washer-dryer	60-in. wide
4B	Washer-dryer	48-in. wide
5A	Sorting table	22 in. + 22 in. divided
5B	Sorting table	18 in. + 18 in. divided
6A	Spool sizer	42-in. wide
6B	Spool sizer	42-in. wide
7	Oversize bagging	2-head manual
8	Bagger	16-head rotary, auto hang and close
9	Bagger (50-lb)	50-lb rotary bagger
10	Baling table	rotary
11	Conveyors	4 @ 20 ft. 3 @ 16 ft.

** Twice cost and capacity of 1000-lb. capacity bulk scoop setup.

Labor when packing 10-lb. bags

Function	Workers
Supply	2
On-line	2
Sorting	8
Oversize	2
Bagging	4
Baling	11
Loading	4
Subtotal	33
Manager	1
Foreman	1
Mechanic	1
Office	1
Total	37

Model Line No. 10
Grading and Packing Round-White Potatoes



Packing Line Equipment

Code	Legend	Nature
1A	Supply system	**
1	Supply system	**
2	Chain sizer	36-in. wide
3	Distrib. conveyor	42-in. wide
4	Washer-dryer	60-in. wide
5	Sorting table	22 in. + 22 in. divided
6	Spool sizer	48-in. wide
7	Oversize bagging	2-head manual
8	Bagger	16-head rotary, auto hang and close
9	Bagger (50-lb)	50-lb. rotary bagger
10	Baling table	rotary
11	Conveyors	4 @ 20 ft. 3 @ 16 ft.

** Twice cost and capacity of 1000-lb. capacity bulk scoop setup.

Labor when packing 10-lb. bags

Function	Workers
Supply	2
On-line	2
Sorting	8
Oversize	2
Bagging	4
Baling	11
Loading	4
Subtotal	33
Manager	1
Foreman	1
Mechanic	1
Office	1
Total	37

ABOUT THE COMPUTER PROGRAMS— POPACK I AND POPACK II

Versatility has been built into these computer programs such that they can be used as aids in designing or re-designing packing lines for round-white potatoes. Any of the 927 pieces of data associated with the programs can be altered, and several variables within the program could be changed in value, allowing for an analysis of practically any combination of variables.

The programs are not completely automatic in arriving at ultimate answers for least cost combinations. In some cases, several trials must be run and human logic or preference applied in the selection of some segments of the packing line equipment or labor unput. This aspect is mandated by the effect of capital-labor substitution at varying lengths of operating season.

Currently, these programs must be run with the assistance of the originator. Should demand indicate the need, the program may be altered and catalogued so that any individual could enter values for the various inputs to custom design a packing line for round-white potatoes.