BULK-HANDLING COMPARED WITH THE USE OF FIELD BOXES WITH REFERENCE TO THE POST-HARVEST PHYSIOLOGY OF APPLES

by

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ABSTRACT

Yellow Newtown apples handled in bulk in large twenty-five bushel bins showed less bruising than those handled in standard one-bushel field boxes. Most of the bruising took place during the dumping on to the grader operation rather than at picking time. The mechanical dumping of the large bins did not cause as severe bruising as did the manual dumping of the field boxes.

The apples bulk handled and stored in the large bins proceeded at a lower respiration rate, maintained a higher sugar level, kept firmer, shrivelled less and were freer from storage physiological disorders than those similarly handled and stored in the standard field boxes.

Storing apples in polyethylene bags kept the fruit in a similar physiological condition to that of apples stored in bulk bins. Evidence presented suggests that storage in large bulk bins effects apples in a beneficial manner similarly to the use of polyethylene box liners and to controlled atmosphere storage.

It was concluded that bulk-handling is beneficial to the

post - harvest physiology of Yellow Newtown apples. It improves their storage qualities, preserves a better appearance and so increases their marketability in comparison to apples which are handled in standard field boxes.

G. Howell Harris,
Professor of Horticulture.

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Robert Combret

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INTRODUCTION

To obtain the ideal in the harvesting of fresh fruit, under present-day conditions, we must correlate two main factors - that is, pick the fruit at a stage of maturity to assure its best edible quality, and handle it in such a way that its quality is maintained during handling and storage. At the same time, costs must be kept as low as possible.

Bulk-handling is of recent introduction in orchard management. More and more growers are adopting this new method of harvesting fruit destined for the fresh market. Most of the experiments carried out to-date in regard to bulk-handling have been conducted in the field of engineering; a very few have been made to determine how bulk-handling affects fruit quality. But nothing has yet been worked out comparing bulk-handling with the use of field boxes in their effects on the post-harvest physiology of apples. It was considered advisable to undertake such a study, especially when bulk-handling is reported as being "the most significant change that has ever occurred in fruit harvesting in the Okanagan Valley" (9).

The materials and methods used in these experiments and the results obtained will be presented and discussed in the second and third parts of this investigation, the first part being dedicated to the historical and descriptive aspects of the most commonly adopted bulk-handling methods.

HISTORY AND DESCRIPTION OF THE MOST COMMONLY ADOPTED BULK-HANDLING METHODS:

Fruit destined for processing has been handled in bulk bins (1), (2) since the early days of processing, but bins were almost exclusively a part of the processing installations and were not used by fruit growers. It was in New Zealand that bulk-harvesting of deciduous fruit was pioneered, in the Nelson and Hawke's Bay districts (3), since the beginning of the 1950s. Instead of the bushel box the New Zealanders used a "thumping big bin" and instead of moving the fruit by hand, they did it with machinery (4).

Some of the earlier types of bulk-handling equipment (13), because they were largely experimental in form, may be considered somewhat crude in design and structure to-day. "Teething" problems, of course, were inevitable but improvements developed rapidly. These improvements largely occurred through the pooling of ideas amongst growers in the industry.

Of the systems so far operated in Hawke's Bay, the main interest is being centred on three types (5), as follow:

The type No. 1, or "Ansa system": The basic equipment for this system is of a proprietary nature and is widely used. In this case, a felt-lined elevator about 18 inches wide replaces the normal grade hopper, and lies at a slight angle towards the end of the grader. A more recent development is a vertical elevator (Fig. 1), the main advantage being a slight saving in shed space. Between the elevator and the grading bench is placed a small hopper which reacts to the weight of fruit being held, in that as this hopper empties, it springs slightly upwards at the elevator end, and by means of a mercury switch control, starts the elevator operating. When the hopper is full of fruit, this control stops the elevator moving, thereby regulating the flow of fruit to the grading bench.

The base of the elevator is sunken into the end of a long concrete well in the floor of the shed, running the same direction as the grader, extending from the hopper end, away from the grader. This well may be 9.5 feet to 15 feet long, 4.5 feet wide and 2.25 feet deep, with the side facing the shed doors sharply bevelled. Along this well travels a flat endless rubber conveyor belt 1.5 feet wide, on special wooden frame 2.75 feet wide. When in motion, this belt moves the fruit slowly towards the elevator.

The fruit is harvested in large trailer bins, fitted with balloon type aircraft wheels and tires, drawn by tractors (Fig. 2). For distant travel on large orchards, three of these bins may be drawn at one time by one tractor. Each of the bins can hold up to 100 bushels of apples or pears. They are made of lumber on prefabricated steel frames and sides, the measurements being 11.75 feet x 5.5 feet x 20 inches. Some growers use linoleum to line the bottoms to avoid chafing of fruit and to allow the free movement of the fruit when tipped. Providing the timber is free of knots, well dressed and well painted, however, a liner such as linoleum does not seem to be necessary.

Usually, two of these full bins are backed into the shed, at right angles to the well, one alongside the other, until they reach a stop rail near the well. The trailer is released from the tractor after the drawbar stand of the trailer is lowered. To commence operation, one of the bins is then tilted towards the conveyor belt in the well by means of a rope and a pulley fixed to the rafters over the drawbar. The tail of the bin then sits on a sloping board near the conveyor belt, and sufficient sliding boards are removed from the end of the bin to allow the fruit to slide out (Fig. 3) on the conveyor belt.

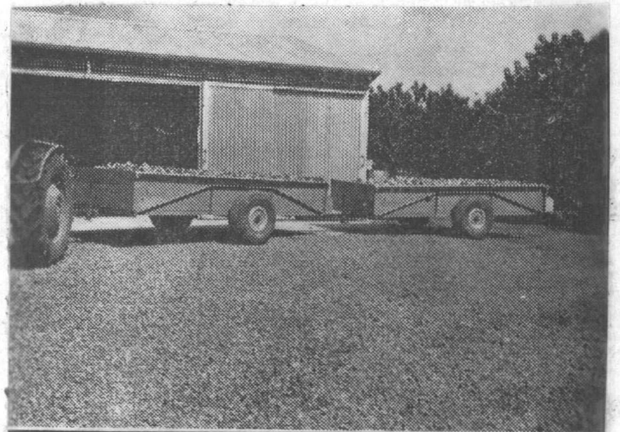
As the electric motor for the equipment is switched on, the fruit is carried slowly along on the belt to the elevator, which picks the fruit up and carries it upwards to the grading control hopper and grading bench. The fruit slides, rather than rolls from the bins to the belt. Before a replacement bin is put into position, the second bin is put into operation, and there is no need for the flow of fruit to stop at any stage.

From eight to fifteen trailer bins are normally used with this equipment with a tendency to higher numbers on large orchards to provide a good reserve and continuous flow of fruit, and to avoid holding up the work of pickers (Fig. 4) during good weather and packing during wet weather. The

Photos N.Z.D.A.

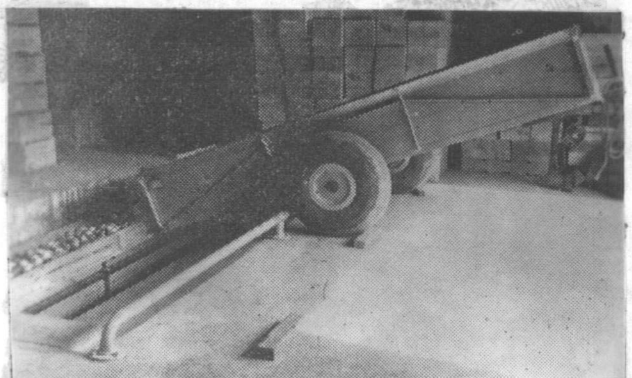
General View: Conveyor belt and elevator carrying fruit to grader hopper.

Fig. 1



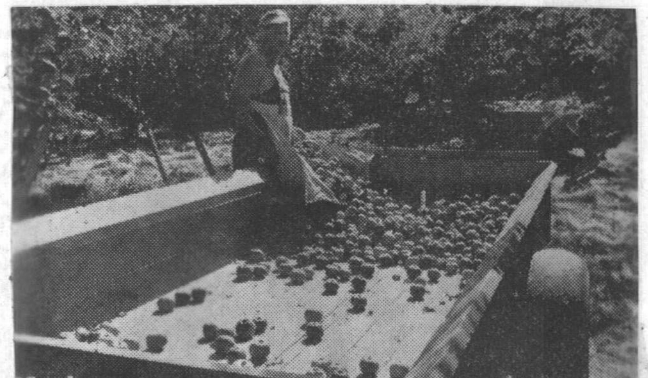
Filled trailer bins arriving at packing shed direct from orchard.

Fig. 2



Trailer bin tilted towards conveyor belt in floor well. Note stop rail.

Fig. 3



Apples being lowered from picking bag into 90-bushel trailer.

Fig. 4

The Ansa system of bulk-handling.

equipment described is reported to operate very smoothly and effectively and bruising is said to be less than with normal methods.

As a result of a brief survey of handling time, it was shown that 1,000 cases of fruit could be handled with this equipment from the tree (including picking) to readiness for final outloading in approximately 143 man-hours, whereas normal methods varied between 230 to 385 man-hours - a very considerable saving. One notable item, carting to packing-shed, from the orchard, the equivalent of 1,000 cases of fruit were handled in 3 man-hours, as compared with normal method of 10 to 20 man-hours. After packing, the fruit is stacked on pallets and then outloaded to motor trucks by means of a standard commercial forklift truck, or by means of a fork-lift attached to the front or rear of a tractor. The latter are operated by rams connected to the hydraulic equipment of the tractors.

If shed space is limited, covers may be needed to protect the fruit in reserve trailers, awaiting handling, and the trailers should preferably be left under the shade of large trees close to the packing-shed.

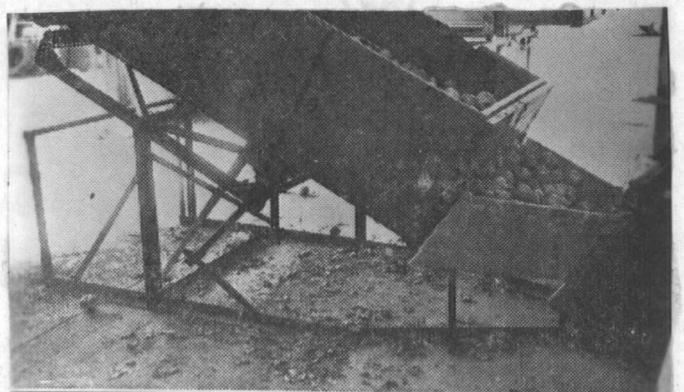
The Type No. 2 or "Hastings system", is another method of bulk handling quite in favour in New Zealand (5). (11). This type of installation is a simpler and much cheaper one, using a tractor-lift to carry rather smaller bins (non-mobile 35-40 loose-bushel capacity) from the orchard to the shed and then placing them on a tilting wooden frame which replaces the grader hopper. This fixed frame (in one case hydraulically-elevated) is made of heavy timber with the top stand sloping towards the grader bench at an angle of about 35 degrees. After a full bin is lowered on to this frame, sliding boards are removed from the end of the bin nearest the grader bench, and the fruit slides, as required, on to the grader. The flow of fruit is largely controlled by the number of boards removed. These bins usually measure about 8 feet x 3.25 feet x 18 inches, but there are many variations, although the depth does not exceed 20 inches.

This type is reported as operating very satisfactorily and the initial cost is reasonable. The tractor lift is also available for loading palleted cases on to a motor truck. Oversize tires, at a higher than normal pressure, are advisable on the tractor for carting in from the orchard. Two of these bins can be carried in from the orchard (Fig. 5), but in such case the tractor must be equipped with dual fork lifts. If desired, two or four of these bins can be carried in from the orchard, placed end to end (with a second layer on top), on a flat 16 feet trailer. This allows the tractor-lift to load or unload each bin, without interference from the centrally situated trailer wheels. The provision of such trailers is a second-year improvement, when the need appears warranted. With ample bins, and reasonable storage space for them in the shed (stacked in tiers), this system provides plenty of reserve fruit. Although the tractor is rather tied to shed for replacement of bins, the tractor-lift has many other uses in the orchard, apart from being the pivot of this system.

The type No. 3, which may be called a "hybrid system" between the two already described, has now been developed and seems to be very popular for average-sized orchards in New Zealand (5), (12). This consists of the use of an elevator and mercury switch controlled hopper at the end of the elevator resting on the shed floor. No well is required for this type. Running at right angles to the elevator is a special type of steel conveyor 4 feet wide mounted on steel supports about 3 feet from floor level. Each bin rests on a separate steel trolley, or frame, which runs on steel wheels along the angle-iron top rail of the conveyor. A section of the conveyor, just opposite the elevator, has a knee action tilting device. The bins (8 feet x 3.25 feet x 20 inches) of fruit are carried from the orchard on a tractor lift, and placed crosswise on the conveyor. Depending on the length of the conveyor, a number of bins can be held in reserve on it and the bins moved along as required, and tilted towards a very small hopper near the foot of the elevator. Once the end boards are removed (Fig. 6) and the elevator equipment put in motion, the fruit slides out of the bin and is picked up by the elevator steps and moved on to the hopper and grader, as described in the Ansa system. When empty, the bins are returned to the flat position and either removed, or pushed along to an extension of the conveyor, and later returned to the pickers by the tractor-lift. Shed doors giving tractor access to each end of the conveyor allow the bins to be put on one end, moved along and emptied, and taken away through the other end. Here

Dual fork lifts on tractor, each carrying 40 loose bushels of fruit.

Fig. 5 Photo N.Z.D.A.



Demonstrating method of tilting bin towards the hopper and elevator.

Fig. 6 Photo N.Z.D.A.

Fig. 7 Photo U.S.D.A.

Tractor lift loads filled pallet boxes onto flat-bed truck for trip to storage.

Fig. 8 Photo U.S.D.A.

above: bulk-handling in New Zealand.

below: bulk-handling in Michigan.

again the tractor-lift is available to load the palleted fruit after packing. This type can be classed as a complete unit to handle the fruit from the tree to final outloading. There is a controlled and steady flow of fruit to the grader, an ample reserve of fruit on the conveyor or stacked in the shed, and because of this, the tractor is not tied to the shed for bin replacement.

The cost of installation depends of course a good deal on the amount of installation work done by the grower himself, such as in the construction of bins or trailer bins, wells, etc. The following figures, however, are reported to give the approximate present cost when systems are fully purchased and installed by tradesmen:

Type No. 1 - £ 1,400 - £ 1,500*

Type No. 2 - £ 400 - £ 500*

Type No. 3 - £ 650 - £ 750*

The above prices include about £ 220 for fork-lift attachments for tractor. The number of bins, trailer bins or flat trailer, etc., considered necessary affect the overall price.

Following are some of the advantages recognized to bulk-handling of deciduous fruit over the use of field boxes in New Zealand (3), (4), (5), (13), and Australia (11), (12):

1. - Harvesting is easier.
2. - pickers show more efficiency.
3. - hauling is made faster.

*The rate of exchange is presently of Can. $ 2.78 for 1£.

4. - savings of 25% or more on picking costs are realized.
5. - contrary to general prediction, the fruit suffers less injury. This is reported particularly apparent with Golden Delicious apples and with peaches.

It is now estimated that more than 90 percent of New Zealand's apple and pear crop are handled in one or another ways of bulk-handling, plus cannery peaches and field tomatoes.

Bulk-handling in North America, as far as fruit destined to the fresh market is concerned, was first developed by the citrus industry of the United States, faced as it is with the problem of high costs and low prices (6). Hence bulk-handling was seen as a good opportunity to reduce harvesting costs.

Bulk-handling of fresh citrus fruit in the United States is generally carried according to three methods as described below:

Bulk-handling in trucks (6), (7), is used by the larger packing-houses where the area served is great, and the fruit must be hauled considerable distances. When picked the fruit is dumped into a mechanical elevator which takes it up into the truck. The fruit does not drop directly from the top of the elevator into the truck, but rolls down a chute, which helps prevent damaging the fruit. This chute is made with a series of hinged sections which can be opened to permit even loading of the truck. The elevator is detachable and when the truck is loaded, the elevator is taken off and the truck hauls the load of fruit to the packing house. One driver handles two trucks, one truck being left in the field to be filled while he takes the second, which has been loaded, to the packing-house. At the packing-house the truck is driven on to a ramp which tips the load towards the conveyor. The truck box is made with the lower half of one side hinged at the bottom. This sideboard is opened and drops, allowing the fruit to roll out on to a broad, roller-type conveyor which slowly moves the load into the plant. The fruit drops off this conveyor on to a wide belt which completes the job of moving the fruit into the packing-house.

Bulk-handling in trailers (6) also called Windermere system (7), is another method, which requires less expensive equipment and is most generally used by smaller packing-houses where the distance from the grove is not so great. The fruit is dumped by the pickers directly into low, specially constructed trailers. No elevator is needed as the trailer box is low. When filled the trailer is towed to the packing-house and on to an inclined ramp which tips it towards the conveyor. The trailer box is constructed with a hinged panel in one side which opens and drops, allowing the fruit to roll out on to a wide conveyor belt which takes it into the packing-house.

Bulk-handling in wire baskets or Sandford system is that method (7) which includes the use of metal baskets and tractors equipped with hydraulic lifting systems to carry these baskets out of the grove and dump the fruit into a semi-trailer truck. The trailer body is equipped with cloth baffles to break the fall of the fruit and to prevent scratching and bruising during loading. The baskets hold the equivalent of 10 boxes* each and every picker has his individual basket. The basket frame is constructed of steel strap and angle iron, with flattened expanded metal welded to the frame to form the body. A solid steel sheet bottom reduces the effect of sand entering when the baskets are placed in the groves. The baskets are designed with sloping sides so that they will fit into one another or "nest" for storage or carrying. The tractor is designed to carry a filled basket on front and rear but can lift and dump only with the hydraulic arms in front. The usual method is for the tractor to bring out two baskets from the grove to the semi trailer. The driver dumps the one held in front and picks up the filled basket left at the dumping site from his previous dumping round and empties this into the semi trailer. He then leaves the filled rear basket near the dumping site and picks up the two empty baskets for return to the pickers. The semi-trailer has a capacity when fully loaded of 420 boxes.

<u>In general, the following advantages</u> are recognized to bulk-handling over the standard system by the citrus industry:

1. - Elimination of the field box either partially or entirely.
2. - Reduction in labor necessary to handle fruit.
3. - Efficiency of picking crews is greatly increased.

* Standard boxes for oranges, lemons and grapefruits weigh respectively 70, 76 and 80 lbs.

4. - Oversized bags may be used if desired.
5. - Increased morale and easier working conditions for workers.
6. - Most of the required labor can be performed by women if necessary.
7. - Increase "effective" capacity of degreening rooms by prior elimination of rots, splits, over and undersized fruit.
8. - Reduction in grade and size variations giving a high percentage of packout from degreening room.
9. - More even flow of fruit through packing-house.
10. - Higher cannery returns for packing-house eliminations.
11. - Reduction of packing-house handling charges on fruit eliminated to cannery.
12. - Washing and Decay control treatments can be accomplished as the fruit enters the packing-house.
13. - Cost analyses (8), (10), show direct savings of between 6.25 cents and 11.25 cents per box (15 to 25%) over standard methods.
14. - Although statistical analysis showed no significant difference between the two treatments on Valencia oranges, the results of 9 experiments conducted on this variety indicated, at three weeks from picking, that all types of losses amounted to 21.7 percent on bulk-handled Valencias as compared with 26.3 percent on boxed fruit.

Bulk-handling of deciduous fruit

Recently bulk-handling has been carefully studied in Michigan (14) but purely as a processor operation. The experiments reported are said to have been under way since 1953 and provide plenty of data. The advantages of bulk-handling over the use of the field box appear to be the following:

(a) To the grower:

1. - A net labor saving of 2.67 cents per bushel of apples handled.
2. - hauling costs reduced by 30 cents per ton per 100 miles.
3. - when fruit is stored in bulk boxes, approximately 10 percent more can be held in a given amount of storage space.
4. - pickers pick about 50 percent more fruit.
5. - the time-consuming task of levelling crates preparatory to stacking is materially reduced.

(b) To the processor:

1. - a saving of 3.3 cents per bushel on labor.
2. - a saving of 6.83 cents per bushel-capacity out of the annual costs of the material.
3. - 10 percent more fruit can be stored in a given amount of space.

(c) To the trucker:

1. - saving in time for loading and unloading.
2. - possibility of carrying more fruit per load, which usually means increased returns.

(d) To the industry: any system which saves time, money and labor for the grower, the trucker and the processor, benefits the entire industry. Figures show that the total per-bushel savings realized when bulk boxes are used amount to 13.45 cents per bushel, just in getting the fruit from orchard to warehouse.

Traditionally, Michigan growers have picked apples into 1-bushel crates which then became the handling and storing container. These crates were assembled by a loading crew and stacked onto pallets for transportation to storage. Recognizing the obvious advantages of bulk handling of apples destined to processing, several of the more progressive growers went to pallet boxes (Fig. 7). The introduction of Generalift wire-bound pallet boxes combines the strength of wood slats and galvanized steel wires to provide sturdy, lightweight bulk containers that can be easily handled in the orchard (15). Filled with 15-bushel loads of apples, pallet boxes are transported by tractor lift (Fig. 8) and truck to the warehouses where they are securely stacked ceiling-high. Instead of moving and spotting 15 individual bushel crates, the Michigan grower now moves one of the lightweight pallet boxes into position near the tree.

It is reported that, in cold storage, 90 bushels of apples can be handled in the space formerly taken up by 78 bushel crates, a saving of over 10% in cold storage space. Ventilation also is said to have been improved through the free flow of forced and refrigerated air through the slatted sides and skid areas. The slates indeed are distant enough to provide for a good aeration and <u>however</u> close enough to avoid bruising the fruit. Incidentally, some Michigan processors believe that the apples stored in bulk boxes keep better than those held in field crates (14), but by the time the present investigation was concluded, no scientific experiment had yet been conducted in order to check this assumption.

Directly from the orchard or from the warehouse, these 15 bushel bins are carried onto a mechanical box dumper which leans the box, thus feeding the conveyor. This mechanical dumper has been developed by J. H. Levin, of the USDA, and H. P. Gaston, of Michigan State University. The dumper was tested in Michigan during the 1956 - 1957 packing season and is now being manufactured for under $ 500. Bruise counts made on 120 bushels of McIntosh apples showed that the use of a bulk box dumper caused from 40 to 50 percent less bruising than the field crate method of handling.

Bulk handling seems then to be well established and its advantages quite recognized in Michigan where an original way of handling apples in bulk has been developed and commercialised.

By the summer of 1956, the Matson Fruit Company, of Selah, Washington, experimentally combined the use of the mechanical Steel Squirrel (instead of a ladder) for picking, with fruit emptied into a tote bin and then swaned out by means of a tractor-mounted rear fork-lift. The Steel Squirrel is an elevating platform unit (16) developed by Blackwelder Mfg. Co., Rio Vista, California. It became equipped with a special fork lift - developed by Yakima (Wash.) Implement Co. - for carrying a 25-box capacity pallet bin for apple picking. When the bag is filled, the picker lowers the platform until the bottom of his bag is on the bottom of the bin, or on the apples in it, and then opens his bag, thus releasing the fruit.

Some Washington growers became interested in the above project about two years ago, as they thought a larger orchard container was needed if they went to any type of fruit harvest mechanization (17). Their first consideration was handling of high quality fruit for the fresh market and maintenance of high quality. Experiments were first run to determine safe depths for handling fruit without bruising. These tests have shown that fruit can be handled in bins as deep as it is convenient to pick into, or even up to about a 3-foot depth of apples for that matter, with no more bruising than is now obtained in normal picking. Incidentally, it may be of interest to mention that the New Zealand Department of Agriculture recommends, in order to avoid undue pressure on the fruit, that the bins do not exceed 18 - 20 inches in depth (5).

Manufacturers in Washington State were working, a year ago, on an experimental bin-dumping equipment for emptying bins (19) of about 25-bushel capacity. Dumpers like those developed in Michigan, dump the bins without undue bruising, but they are of intermittent flow and of smaller capacity than needed for the size of the usual Washington fruitpacking plants.

Estimates, done in 1953 by the Fruit Industries

Research Foundation, were that bulk boxes would save at least 8 cents in direct cost per bushel handled, plus saving coming from better handling, possible better utilization of storage space and other indirect savings. Continuing its work, the Foundation established the features of the ideal bulk box (17). This is regarded as one of the most important contributions of Washington's apple industry; especially at a time when a number of boxes of different width, length, depth, materials, are being constructed, without realizing the obvious advantages to the industry of standardizing on the dimensions and if possible on the type of box. According to this study, the most important characteristics of the ideal bulk box should be the following:

1. - to keep bruise damage to a minimum.
2. - to be of a nesting or an easily knocked down type.
3. - to be light in weight.
4. - to be designed in such a way that dumping will be made without damage and inexpensively.
5. - to be of such dimensions and design that stacking in storage, in the refrigeration cars and for hauling on a road truck will be easy.
6. - the design of the bulk box should assure adequate cooling in cold storage. How can this ventilation be provided without using cracks that may cause damage on the fruit?
7. - the ideal bulk box should be useable for more than apples.
8. - the ideal bulk box, if possible, should be uniform in the industry.

These values can come to the industry quickly through intensified research on the problem. Otherwise, many who go to bulk boxes may find their choice of box partly obsolete within a few years.

However, the idea of bulk-handling aroused widespread interest in the Pacific Northwest only after being promoted by Dr. James C. Marshall, in charge of the Dominion Entomological Laboratory, at West Summerland, B. C. Dr. Marshall encountered this method of harvesting (4) when he was in New Zealand and Australia, on other research work. On his return, he published several descriptive articles on bulk-handling "down-under" in various journals of the industry, in all the Pacific Northwest. Following Dr. Marshall's reports, a mission composed of several B. C. growers journied south of the equator to study bulk handling, and came back enthusiastic enough about the subject to persuade their neighbors to join in the experiment. However, the report published (18) by two members of the group on their return points out that many difficulties face growers in the Pacific Northwest in adapting ideas developed "down under". Standardization of the size of the bins used is recommended as one of the first steps necessary. It appears that one of the major differences between the fruit industries of the northern and southern hemispheres is that in the Antipodes practically all fruit packing is done by the grower himself in his own packing shed. In a few cases a grower may pack the fruit from a neighboring orchard. In a few rare instances half a dozen growers have formed co-operatives, but these are quite selective. The report claims the following advantages for bulk handling:

1. elimination of: (a) stacking boxes as they are filled in the orchard.
   (b) putting full boxes on trailers.
   (c) taking full boxes from trailers.
   (d) trucking full boxes to dumper.
   (e) dumping full boxes.
   (f) collecting empty boxes left on orchard.
   (g) repairing picking boxes.
2. pickers have increased efficiency.
3. bruising and stem punctures are reduced.
4. a substantial saving is made in cold storage space.

It is pointed out however that a change-over would require the settlement of many problems, which include:

(a) The problem of a hillside orchard (most of the orchards in New Zealand are on flats).
(b) Spotting bins for greatest convenience of pickers.
(c) Organizing tractor operation in getting empty bins out and full ones in.
(d) Handling full bins.
(e) Organizing succession of full bins in and empties out at the packing house.
(f) How many trailers and bins are necessary.
(g) Storage problems in keeping growers' bins separated awaiting packing.

No accurate figures were obtainable either in New Zealand or Australia on the cost of a change-over, but it was estimated that the total capital investment could be paid off in three years by savings effected, primarily in orchard labor and in picking box repair. Additional gains were credited to a lower cull rate and better grade. Most important, much of the hard work was taken out of harvesting.

Then, after much thought and discussion, the fruit industry in the Okanagan Valley was prepared to take the first steps in initiating a bulk handling program. At least four fruit packing organizations indicated their intentions (19) to handle a portion of the crop in 25-bushel containers. The Vernon Fruit Union alone purchased five thousand of these bins. This was considered to be the first major group of growers to swing over to the bulk method of harvesting in the Pacific Northwest.

One of the most important steps taken in the Okanagan Valley, with regard to the bins, was standardization of outside dimensions. A committee of the Okanagan Federated shippers was appointed to make recommendations for a standard size bin. The following (19) dimensions were approved:

Overall length : 48 inches
overall width : 43 inches
inside depth : 24 inches
overall height including integral pallet: 29 - 30 inches.

All bins in use in the Valley are of these dimensions and hold 25 bushels of apples or pears. At about the same time these dimensions were adopted, the North West Equipment Company, of Wenatchee, Washington, had developed equipment suitable for automatically dumping bins having approximately the above dimensions. Mechanical dumping of the bins was later on adopted rather than the gravity flow from end doors which functions so successfully where long relatively shallow bins are used, similar to those in New Zealand.

The sides of the bins in use are 0.5" plywood and the bottoms, 5/8" plywood. The 0.5" sides appear satisfactory but 0.75" bottoms are now being recommended for the new bins to be built this season (9). The corner posts are 4" x 4" cut diagonally. The corner posts also form legs for the bin. Two runners are provided under the legs. A metal bracket is used on two sides to tie the side and bottom together. Bins to be built this season will be reinforced, however, with a galvanized steel strap 0.75" x 0.023" about 1.5" from the top to prevent bulging; annular ring nails will be used on the corners of most new bins.

The most important piece of equipment, as far as most growers are concerned, is a simple rear fork-lift (Fig. 9) mounted on the 3-point hitch of the tractor (cost: $85.00). This unit is used to carry partly filled bins within the orchard, to carry full bins to a loading area, to load full bins on a trailer, or truck deck (where the deck can be placed so that the lift is not over eighteen inches or so), and to distribute empty bins in the orchard. A few growers have purchased lift equipment for attachment to a tractor or truck, capable of lifting two full bins and loading them on a truck deck. Commercial haulers also use this type of equipment for loading bins on truck or trailers.

Some growers leave the bins on a trailer when picking,

Fig. 9

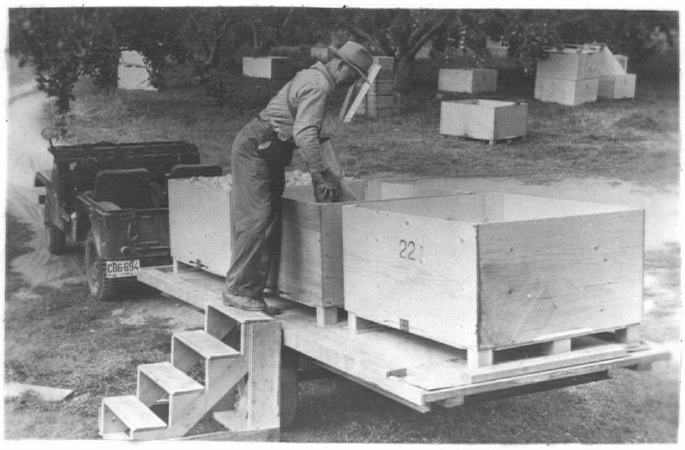


Fig. 10

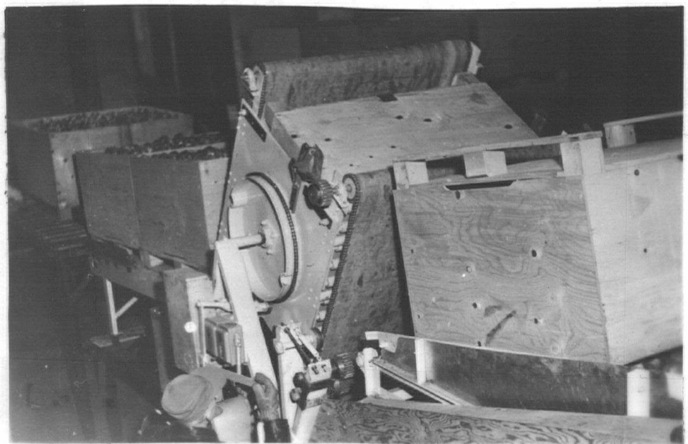


Fig. 11 Photos Canada Agriculture

Bulk-Handling in the Okanagan Valley.

and then haul the load directly to the packing house on the trailer(Fig. 10). At the packing-house, the bins are handled with a regular fork-lift equipment of suitable capacity. Most of these lifts will lift three full bins at a height of about 13 feet. The bins are dumped by complete inversion in a specially designed (Fig.11) mechanical dumper (9). In this case the fruit leaves from the top of the bin. Some bins were made with end-gates. These were dumped by elevating one end and allowing the fruit to leave the bin through a gate on the other end. Forcasts for the coming season are that at least 15,000 bins will be used in the Valley. Much interest was shown in Washingto State about the movement favouring bulk-handling in the Okanagan and the matter was discussed at the 53rd convention of the Washington State Horticultural Association, held in Wenatchee in the early days of December 1957

In the Okanagan, last fall, a limited number of records were kept of the time for various operations. It was concluded (9) that, in the same time, a picker was able to pick 10 per cent more fruit into bins than into boxes and one man could easily haul twice as much fruit from the orchard floor to a loading area. Depending on the lay-out of the storage(9) a saving of 15 to 40 percent in storage space was effected at the packing house.

POSTHARVEST PHYSIOLOGY

From the foregoing it would appear that much is already known about the economical and mechanical aspects of bulk-handling of apples. In contrast there appears to be very little information available in regard to the effects of bulk handling on the post-harvest physiology of the fruit.

What happens to the fruit in storage, in marketing channels and in the hands of the consumer is of vital concern to the fruit handler who desires to preserve the fruit in a good and attractive condition for as long as possible.

Bruising, for example, may directly affect eating quality or it may be a psychological factor: badly bruised apples do not look very appetizing.

Apples, in the fresh state, are living material. The process by which living materials use sugar, or other substances, for energy, is that of respiration. The usual method of preserving fresh apples is by cold storage. This reduces the respiration rate by maintaining the temperature of the storage at 32-35° F.

Another form of storage, known as controlled atmosphere storage (gas storage), is now in limited use. In this type of storage, a higher concentration of carbon dioxide and a lower concentration of oxygen than is normally found in the air is used. This has an effect on the respiration of the fruit (21) similar to a temperature reduction. Higher temperatures can be used in gas storage and so certain cold storage disorders are avoided.

The following experiments were conducted to ascertain information on the effects of bulk-handling on the post-harvest physiology of apples. The respiration rate, the loss in weight, the sugar content, the observed mechanical injury, the rate of softening of the fruit and the presence or absemce of certain physiological storage disorders were evaluated for this purpose.

MATERIALS AND METHODS

The apples were obtained through the co-operation of Mr. C. Elsey, manager of the Occidental Fruit Company Ltd., West Summerland, British Columbia. The investigation consisted of three parts:

Experiment I:-

One lot was selected at random from Yellow Newtown apples picked into and stored in 25-bushel Okanagan-type bulk bins. The other, from apples picked and stored in standard bushel boxes. Both lots had been held for 85 days after picking under identical cold storage conditions in the company warehouse - that is, at 32-34° F and 85% of relative humidity. Each lot consisted of one bushel of fruit.

These apples were transported carefully by private auto to Vancouver and placed immediately in a cold storage at 33° F and the following analyses were conducted in the plant nutrition laboratory at the University of British Columbia: mechanical injury, respiration rates, firmness, sugars content and loss in weight (shrivelling).

Mechanical injury was evaluated by measuring and recording the amount of bruising and stem punctures on the apples, taking a score of 4 for 0.5" bruising. Respiration was determined by placing samples in gas-tight chambers of 4,650 cc capacity for 24 hours at room temperature. At the end of this period, the amount of CO_2 given off by the fruit - that is, the percentage of CO_2 in the gas chamber, was recorded

(20) with a D'Orsat gas analyzer (Fig. 12). The weight of the apples and their volume were determined and the results expressed as milligrams of CO_2 evolved per hour per kilogram of fruit.

Firmness was tested with a Ballauf pressure tester (22) which is the standard instrument used by horticulturists for this purpose. Juice was expressed from the samples and the total sugars content determined, using a refractometer. The loss of weight was recorded on each sample over a 24-hour period.

Experiment II:-

This experiment involved two bushels of Yellow Newtown apples, one of which weighed 16,432.6 grams and contained 120 bulk-handled apples. The other weighed 16,434.3 grams and contained also 120 field-boxed apples. The fruit, this time, had been graded, which means that it had been bulk-handled, or field-boxed, "all the way" from the orchard to the grader, and finally wrapped and packed. The apples were now in their 125th day of storage (same conditions as in Experiment I) after harvest. Bulk-handled apples had been dumped mechanically, as illustrated by Fig. 11 and described in part I, while boxed apples were dumped manually on the conveyor. In this case, besides the effects of a longer storage period, any mechanical injury caused to the fruit by both handling methods was put in evidence.

The determinations made were the same as in Experiment I.

Fig. 12 Photo by the author

A d'Orsat apparatus and respiration chamber.

Experiment III:-

A third experiment was set up to ascertain the effects of different types of packaging on shrivelling, respiration, firmness and sugar content of McIntosh apples. The same determinations were performed as in Experiment I. The apples, 48 in number, were divided into four equal groups and treated as follows:

a) - 12 were left unpacked, being used as check-samples.

b) - 12 were waxed by brushing the surface several times with a coating of parawax.

c) - 12 were wrapped in standard oiled papers.

d) - 12 were placed into sealed polythylene (150 gauge) liners.

All the apples were then placed in cold storage (33-34° F and 85% R. H.) for 105 days, after which period the above-mentioned determinations were made.

This experiment was conducted to note whether there was any similarity in the post harvest response of bulk-bin handled apples to those stored using other techniques.

EXPERIMENTAL RESULTS

Experiment I Results:

The effects of bulk bin and standard box handling on shrivelling, respiration, firmness, bruising and sugar content of Yellow Newtown apples after 85 days of storage in their field containers are shown in summarized data below in table 1 and the chart of page 36.

The complete data together with statistical analyses (23) are presented in the tables I to VI inclusive of the appendix.

Table 1.

Determinations	Bulk handled apples	Box handled apples	Difference	Significant Difference P = 0.05	P = 0.01
average loss of weight in grams	1.185	1.745	0.560**	0.310	0.3999
respiration mg of CO_2 per kg per hr	13.55	23.69	10.14**	2.890	3.7281
bruising score: 4=0.5" br	12.20	13.65	1.45	5.268	-
firmness in lbs	12.680	12.285	0.395	0.4752	-
sugar content in percent	13.595	12.935	0.660**	0.482	0.62178

The above table shows that the bulk-handled apples lost less weight, respired more slowly and maintained a higher sugar content than the box-handled apples. On the other hand there was no statistical difference in bruising and firmness of the apples handled by the two methods.

Experiment II Results:-

The effects of bulk bin and standard box handling on shrivelling, respiration, firmness, bruising and sugar content of Yellow Newtown apples after 125 days of storage in their field containers are expressed in summarized data below in table 2 and the chart of page 36 .

The complete data together with statistical analyses (23) are presented in the tables VII to XII inclusive of the appendix.

Table 2.

Determinations	Bulk handled apples	Box handled apples	Difference	Significant Difference P = 0.05	P = 0.01
average loss of weight in grams	1.195	1.730	0.535**	0.2436	0.314244
respiration mg of CO_2 per kg per hr	18.745	31.245	12.5 **	0.750	0.9675
bruising score: 4=0.5"br.	26.15	37.85	11.70 **	4.304	5.55216
firmness in lbs.	14.45	14.01	0.44 *	0.342	0.44118
sugar content in percent	14.07	13.53	0.54 **	0.3072	0.396288

The above table showing data taken after 125 days in storage indicates similar trends to those taken 85 days after storage. In this case, however, the differences in respiration between the samples from the two types of handling are intensified. Furthermore, differences in bruising are now highly significant whereas in Experiment I they were not significant. The difference between the losses of weight in both treatments and the difference between sugar contents have also remained highly significant.

Experiment III Results:-

The effects of different types of packaging on shrivelling, respiration, firmness and sugar content of McIntosh apples after 105 days of storage are expressed in the summarized data below in table 3.

The complete data are presented in table XIII of the appendix.

Table 3.

Determinations	Check	waxed	wrapped	Polyethylene liner
average loss of weight in grams	2.10	1.10	1.65	0.90
respiration mg of CO_2 per kg per hr	27.40	22.85	24.15	11.70
firmness in lbs	8.25	8.35	8.20	9.10
Sugar content in percent	11.95	12.45	11.90	13.10

The above table shows that the loss of weight was lessened by all treatments, and that polyethylene liner markedly did so. Respiration was also pronouncedly kept to a minimum by the polyethylene liners which also maintained firmness and sugar content at a maximum.

DISCUSSION OF RESULTS

The results of Experiments I and II are expressed graphically in Fig. 13 in order to facilitate the following discussion.

Bulk handling of Yellow Newtown Apples resulted in an appreciable decrease in the rate of respiration as compared with the apples handled in field boxes. On the 85th day in storage, the respiration rate of the bulk-handled Yellow Newtowns was 13.55 mg of CO_2 evolved per kilogram of fruit and per hour, as compared with 23.69 mg for the field box handled apples. Forty days later, the rate of respiration was higher in both cases but was proceeding more rapidly in the samples from the field boxes. This maintaining of a lower rate of respiration in the apples from the bulk bins could be explained as follows:

In consequence of the large volume of fruit in the bulk bins in contrast to the small volume of fruit in the bushel-box containers, there was a greater "build up" of CO_2 in the bins. This CO_2 increase, being an end-product of respiration, would tend to slow down the rate of the respiration processes.

Moreover, the amount of oxygen available and circulating around the fruit would be greater in the field boxes than in the bulk bins. This increase in available oxygen would also tend to speed up the respiration processes.

We therefore have, in the bulk bins, a decreased oxygen supply available to the fruit and an increased CO_2 supply. Both these factors would slow down respiration, in comparison to the field boxes where O_2 is higher and CO_2, lower.

It is recognized that, if the field boxes developed a higher temperature than the bins, this would contribute to a higher respiration rate of the fruit in the field boxes. However, the reverse is more likely to be true. Namely that, owing to the larger volume of fruit, temperature would actually be higher in the bins. In this experiment, no difference in temperature between the two were detected. McMechan reported (9) to have found no significant difference in the cooling rate of bins and boxes with the exceptions of bins with bottom slots whereby the bins cooled a little faster but not significantly so. The bins used in these experiments however were not provided with such openings.

It would seem that other factors than temperature were responsible for the reduced rate of respiration of the bulk-handled apples. The fact that sugars in the fruit were maintained at a significantly higher level in bins than in boxes indicated that less had been used in respiration, as also did the fact that there was less shrivelling.

It would appear then that we have a condition, in the bulk bins, somewhat akin to commercial gas storage where fruit is maintained for relatively long periods, at a somewhat higher temperature than in standard cold storage, in excellent condition. Gas storage is operated on the principle that the rate of respiration - hence

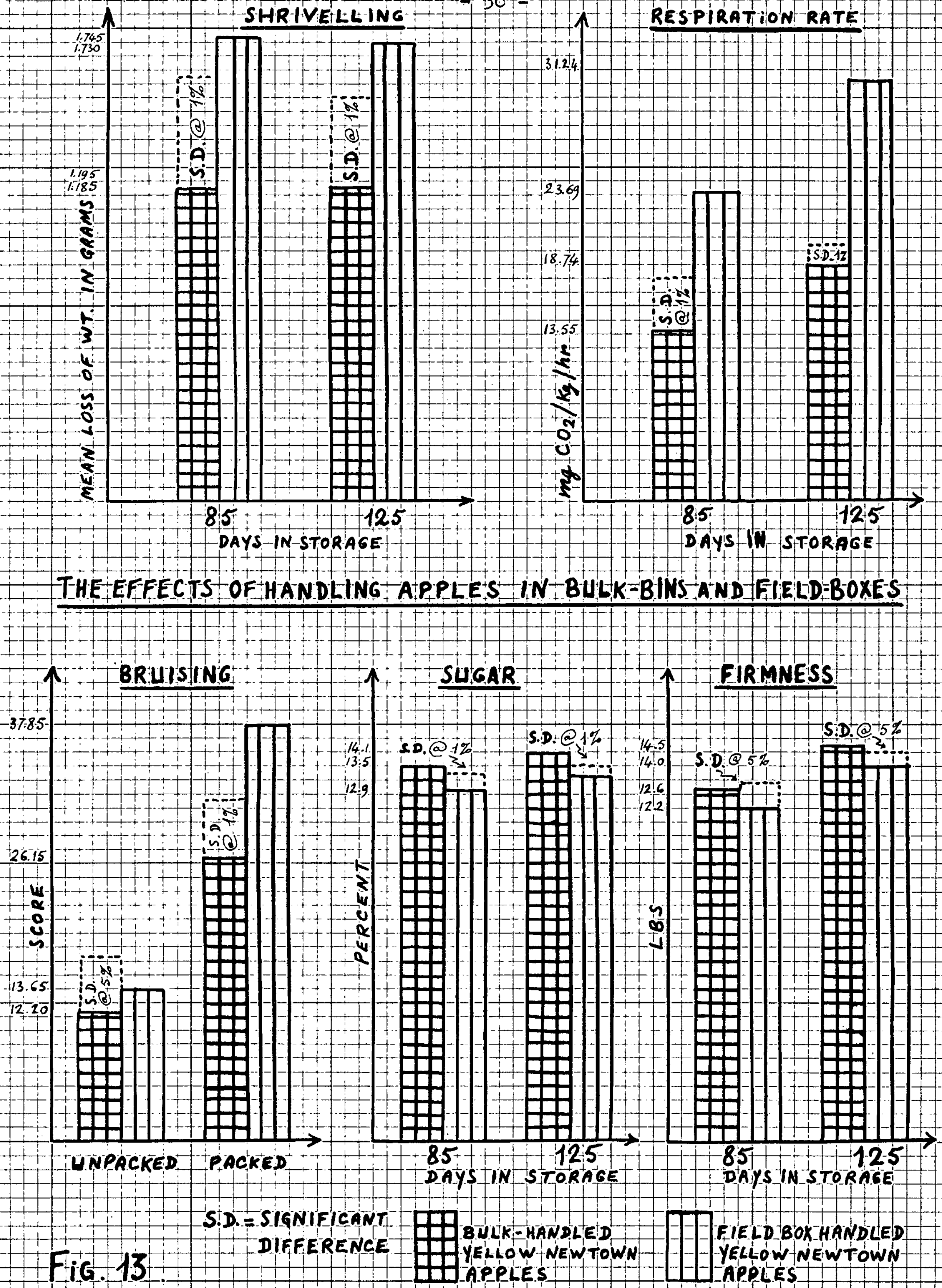

SHRIVELLING
MEAN LOSS OF WT. IN GRAMS
1.745
1.730
1.195
1.185
S.D. @ 1%
S.D. @ 1%
85
125
DAYS IN STORAGE
RESPIRATION RATE
mg CO2/Kg/hr
31.24
23.69
18.74
13.55
S.D. @ 1%
S.D. 1%
85
125
DAYS IN STORAGE
THE EFFECTS OF HANDLING APPLES IN BULK-BINS AND FIELD-BOXES
BRUISING
SCORE
37.85
26.15
13.65
12.20
S.D. @ 5%
S.D. @ 1%
UNPACKED
PACKED
SUGAR
PERCENT
14.1
13.5
12.9
S.D. @ 1%
S.D. @ 1%
85
125
DAYS IN STORAGE
FIRMNESS
LBS
14.5
14.0
12.6
12.2
S.D. @ 5%
S.D. @ 5%
85
125
DAYS IN STORAGE
S.D. = SIGNIFICANT DIFFERENCE
BULK-HANDLED YELLOW NEWTOWN APPLES
FIELD BOX HANDLED YELLOW NEWTOWN APPLES

FIG. 13

the keeping qualities of the fruit - is lengthened by:

(a) reducing the O_2 content of the chamber.

(b) increasing the CO_2 content of the chamber.

(c) a combination of both.

To further substantiate this view, the Experiment III gives added enlightenment. Apples stored in polyethylene liners behaved similarly to those in the bulk bins. Respiration was reduced; sugars, moisture content and firmness were maintained at a maximum. It is known that polyethylene liners play the role of a small controlled atmosphere storage. Other workers (24) have found that storage troubles of Yellow Newtown Apples could be reduced by polyethylene liners.

It is also known (21) that gas storage reduces the amount of physiological storage diseases such as brown core and internal breakdown (Fig. 18), soft scald (Figs. 16 and 17) and bitter pit (Fig. 15). While this investigation was not designed to obtain information on these diseases and consequently no planned experiment was previously mentioned , nevertheless it was found that these storage disorders were more prevalent in the box handled fruit although insufficient numbers were found to make a statistical analysis (see Figs. 15, 16, 17 and 18).

All the evidence obtained suggests that the bulk bins behave in the nature of gas storage units and for this reason contribute to better storage of fruit in them than in the bushel-boxes.

The data presented about bruising are of interest. It would appear that while there was no significant difference in bruising between the apples picked respectively into bulk bins or bushel-boxes and placed in storage up to packing time, there was a marked difference after dumping on to the conveyor for packing. This indicates that the most bruising (Fig. 14) damage is done by dumping the fruit in the packinghouse on to the grader and that the mechanical dumping of bins causes less bruises and injury than the manual dumping of field boxes.

The result of this investigation shows that bulk-handling of Yellow Newtown apples, besides being a more economical way of handling the fruit, causes less injury to the fruit and preserves it in better condition than that handled in field boxes.

Fig. 14 Bruising

Fig. 15 Bitter pit

Fig. 16 Soft scald

Fig. 17 Soft scald

Fig. 18 Brown core and internal breakdown.

Photos by the Author.

Some typical bruising and physiological disorders found in the investigation.

CONCLUSIONS

Bulk handling of apples resulted in an appreciable decrease in the bruising of Yellow Newtown variety compared to those handled in standard field boxes. Most bruising occured during the dumping of the fruit from the containers on to the conveyor during the grading process.

The mechanical dumping of the fruit in the bulk bins caused less bruising than did the manual dumping of field boxes during the grading process.

Compared to fruit handled in field boxes, bulk-handling kept the rate of respiration of the apples at a relatively low level, reduced shrivelling, was responsible for firmer fruit, maintained the sugar content at a higher level and minimized storage disorders.

The marketability of the apples was increased by bulk-handling which also, as shown by the literature reviewed, is a more economical way to handle the fruit than in field boxes.

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APPENDIX

Table I*. Experiment I. The effects of bulk-handling on Yellow Newtown Apples.

Sample No	Apples No	weight before (gram)	weight after (gram)	weight lost (gram)	apples vol (cc)	air vol in can (cc)	CO_2%	CO_2(mg kg/hr	pressure (lbs)	sugar (%)	bruising
1	7	900.6	898.9	1.7	1126	3524	3.9	12.5	13.2	12.6	15
2	7	919.4	918.2	1.2	1149	3501	4.0	15.1	13.5	14.2	18
3	6	861.7	860.8	0.9	1077	3573	3.8	12.9	14.0	14.0	16
4	5	657.3	656.6	0.7	822	3828	3.2	15.2	14.2	13.6	2
5	5	551.9	550.5	1.4	690	3960	3.8	22.3	13.4	13.2	15
6	6	722.5	720.2	2.3	903	3747	4.1	17.4	14.3	14.0	5
7	6	834.2	833.0	1.2	1043	3607	3.6	12.7	11.6	13.5	17
8	5	699.8	699.0	0.8	875	3775	2.5	11.0	12.3	14.2	12
9	5	804.1	803.5	0.6	1005	3645	3.7	14.1	11.5	13.2	8
10	6	764.5	763.0	1.5	956	3694	4.1	16.2	11.7	12.1	23
11	6	655.8	654.1	1.7	820	3830	2.8	13.4	13.9	15.0	16
12	6	801.2	799.4	1.8	1002	3648	3.4	12.6	11.8	12.1	17
13	4	692.3	691.4	0.9	865	3785	2.6	11.8	12.7	13.9	8
14	5	553.1	552.8	0.3	691	3959	2.9	17.0	12.5	14.1	11
15	5	618.9	617.2	1.7	874	3776	2.8	14.0	11.4	13.8	8
16	4	641.4	640.7	0.7	802	3848	1.8	8.8	11.8	13.9	6
17	5	605.0	603.8	1.2	756	3894	2.0	10.5	12.2	13.1	15
18	5	621.3	620.3	1.0	777	3873	1.8	9.2	11.7	13.3	16
19	5	711.6	710.2	1.4	890	3760	2.7	11.6	13.2	14.2	5
20	5	645.2	644.5	0.7	807	3843	2.6	12.7	12.7	13.9	11
Total	108	14,261.8	14,238.1	23.7				271.0	253.6	271.9	244
Mean				1.185				13.55	12.68	13.595	12.20

* Cont. on next page.

Table I (Cont.). Experiment I. The effects of field-box handling on Yellow Newtown Apples.

Sample No	Apples No	weight before (gram)	weight after (gram)	weight lost (gram)	apples vol. (cc)	air vol in can (cc)	CO_2%	CO_2(mg kg/hr	pressure (lbs)	sugar (%)	bruising
1	5	766.1	764.2	1.9	955	3695	5.2	20.5	12.2	12.6	35
2	6	897.0	895.3	1.7	1121	3529	5.4	17.4	12.1	12.5	29
3	5	804.4	803.6	0.8	1006	3646	6.3	23.4	13.0	12.2	15
4	6	799.2	798.1	1.1	999	3651	5.8	21.7	12.5	13.0	10
5	6	739.8	737.9	1.9	925	3725	6.5	26.8	12.4	13.5	7
6	5	827.1	825.8	1.3	1034	3616	7.2	25.8	12.3	12.1	14
7	5	846.4	744.5	1.9	933	3717	6.0	24.5	13.5	14.4	7
8	5	749.0	747.6	1.4	936	3714	4.7	19.1	12.0	13.5	4
9	6	989.5	987.8	1.7	1237	3413	4.6	13.0	11.7	13.3	27
10	6	825.2	823.4	1.8	1032	3618	4.9	17.6	12.2	14.0	38
11	5	710.5	708.7	1.8	888	3762	6.6	28.6	12.7	13.4	10
12	5	603.2	601.8	1.4	754	3896	4.6	24.3	12.4	11.2	6
13	4	612.1	610.0	2.1	765	3885	4.8	24.9	12.3	13.8	5
14	4	557.8	555.1	2.7	691	3959	6.4	37.2	11.7	13.4	18
15	5	628.3	627.1	1.2	785	3865	5.3	26.7	12.0	12.7	9
16	5	507.2	505.3	1.9	634	4016	5.4	35.0	12.2	13.5	14
17	4	676.7	675.2	1.5	846	3804	4.1	18.9	11.8	12.0	10
18	4	623.6	620.9	2.7	780	3870	4.4	22.3	12.6	12.3	8
19	4	609.4	607.6	1.8	762	3888	4.6	24.0	12.1	13.1	3
20	4	580.7	578.4	2.3	726	3924	4.0	22.1	12.0	12.2	4
Total	99	14,253.2	14,218.3	34.9				473.8	245.7	258.7	273
Mean				1.745				23.69	12.285	12.935	13.65

Table II. Experiment I. The comparative effects of bulk and box-handling on the shrivelling* of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	Deviation^2	B=box	Deviation −	Deviation +	Deviation^2
1	1.7		0.515	0.265225	1.9		0.155	0.024025
2	1.2		0.015	0.000225	1.7	0.045		0.002025
3	0.9	0.285		0.081225	0.8	0.945		0.893025
4	0.7	0.485		0.235225	1.1	0.645		0.416025
5	1.4		0.215	0.046225	1.9		0.155	0.024025
6	2.3		1.115	1.243225	1.3	0.445		0.198025
7	1.2		0.015	0.000225	1.9		0.155	0.024025
8	0.8	0.385		0.148225	1.4	0.345		0.119025
9	0.6	0.585		0.342225	1.7	0.045		0.002025
10	1.5		0.315	0.099225	1.8		0.055	0.003025
11	1.7		0.515	0.265225	1.8		0.055	0.003025
12	1.8		0.615	0.378225	1.4	0.345		0.119025
13	0.9	0.285		0.081225	2.1		0.355	0.126025
14	0.3	0.885		0.783225	2.7		0.955	0.912025
15	1.7		0.515	0.265225	1.2	0.545		0.297025
16	0.7	0.485		0.235225	1.9		0.155	0.024025
17	1.2		0.015	0.000225	1.5	0.245		0.060025
18	1.0	0.185		0.034225	2.7		0.955	0.912025
19	1.4		0.215	0.046225	1.8		0.055	0.003025
20	0.7	0.485		0.235225	2.3		0.555	0.308025
Total	23.7	4.065	4.065	4.785500	34.9	3.605	3.605	4.469500
Mean	1.185 gram				1.745 gram			

$$S.D._A = \sqrt{\frac{4.7855}{19}} = 0.5011 \qquad S.D._B = \sqrt{\frac{4.4695}{19}} = 0.4850$$

$$E_A = \frac{0.5011}{\sqrt{20}} = 0.112 \qquad E_B = \frac{0.4850}{\sqrt{20}} = 0.108$$

$$E_D = \sqrt{(0.112)^2 + (0.108)^2} = 0.155 \text{ gram}$$

$$D = 1.745 - 1.185 = 0.560 \text{ gram}$$

at the 5% level, t = 2 and 0.155 x 2 = 0.310 gram

at the 1% level, t = 2.581 and 0.155 x 2.58 = 0.3999 gram

but 0.560 > 0.3999; hence, the difference between both treatments is highly significant.

*Weight in grams lost by each sample over a 24-hour period.

Table III. Experiment I. The comparative effects of bulk and box-handling on the respiration rate* of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	Deviation^2	B=box	Deviation −	Deviation +	Deviation^2
1	13.5	1.05		1.1025	20.5	3.19		10.1761
2	15.1		1.55	2.4025	17.4	6.29		39.5641
3	12.9	0.65		0.4225	23.4	0.29		0.0841
4	15.2		1.65	2.7225	21.7	1.99		3.9601
5	22.3		8.75	76.5625	26.8		3.11	9.6721
6	17.4		3.85	14.8225	25.8		2.11	4.4521
7	12.7	0.85		0.7225	24.5		0.81	0.6561
8	11.0	2.55		6.5025	19.1	4.59		21.0681
9	14.1		0.55	0.3025	13.0	10.69		114.2761
10	16.2		2.65	7.0225	17.6	6.09		37.0881
11	13.4	0.15		0.0225	28.6		4.91	24.1081
12	12.6	0.95		0.9025	24.3		0.61	0.3721
13	11.8	1.75		3.0625	24.9		1.21	1.4641
14	17.0		3.45	11.9025	37.2		13.51	182.5201
15	14.0		0.45	0.2025	26.7		3.01	9.0601
16	8.8	4.75		22.5625	35.0		11.31	127.9161
17	10.5	3.05		9.3025	18.9	4.79		22.9441
18	9.2	4.35		18.9225	22.3	1.39		1.9321
19	11.6	1.95		3.8025	24.0		0.31	0.0961
20	12.7	0.85		0.7225	22.1	1.59		2.5281
Total	271.0	22.90	22.90	183.9900	473.8	40.90	40.90	613.9380

Mean 13.55 mg/kg/hr 23.69 mg/kg/hr

$S.D._A = \sqrt{\frac{183.99}{19}} = 3.1118$ $S.D._B = \sqrt{\frac{613.938}{19}} = 5.6844$

$E_A = \frac{3.1118}{\sqrt{20}} = 0.69$ $E_B = \frac{5.6844}{\sqrt{20}} = 1.27$

$E_D = \sqrt{(0.69)^2 + (1.27)^2} = 1.445$ mg

$D = 23.69 - 13.55 = 10.14$ mg

at the 5% level, $t = 2$ and $1.445 \times 2 = 2.890$ mg

at the 1% level, $t = 2.58$ and $1.445 \times 2.58 = 3.7281$ mg

but $10.14 > 3.7281$; hence, the difference found is highly significant.

*milligrams of CO_2 evolved per kilogram of fruit and per hour.

Table IV. Experiment I. The comparative effects of bulk and box-handling on the bruising* of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	Deviation^2	B=box	Deviation −	Deviation +	Deviation^2
1	15		2.80	7.84	35		21.35	455.8225
2	18		5.80	33.64	29		15.35	235.6225
3	16		3.80	14.44	15		1.35	1.8225
4	2	10.20		104.04	10	3.65		13.3225
5	15		2.80	7.84	7	6.65		44.2225
6	5	7.20		51.84	14		0.25	0.1225
7	17		4.80	23.04	7	6.65		44.2225
8	12	0.20		0.04	4	9.65		93.1225
9	8	4.20		17.64	27		13.35	178.2225
10	23		10.80	116.64	38		24.35	592.9225
11	16		3.80	14.44	10	3.65		13.3225
12	17		4.80	23.04	6	7.65		58.5225
13	8	4.20		17.64	5	8.65		74.8225
14	11	1.20		1.44	18		4.35	18.9225
15	8	4.20		17.64	9	4.65		21.6225
16	6	6.20		38.44	14		0.35	0.1225
17	15		2.80	7.84	10	3.65		13.3226
18	16		3.80	14.44	8	5.65		31.9225
19	5	7.20		51.84	3	10.65		113.4225
20	11	1.20		1.44	4	9.65		93.1225
Total	244	46.00	46.00	565.20	273	80.80	80.80	2,098.5500
Mean	12.20				13.65			

$$S.D._A = \sqrt{\frac{565.20}{19}} = 5.435 \qquad S.D._B = \sqrt{\frac{2,098.55}{19}} = 10.510$$

$$E_A = \frac{5.435}{\sqrt{20}} = \frac{5.435}{4.473} \text{ or } 1.21$$

$$E_A = \frac{10.510}{\sqrt{20}} = \frac{10.510}{4.473} \text{ or } 2.34$$

$$E_D = \sqrt{(1.21)^2 + (2.34)^2} = 2.634$$

$$D = 13.65 - 12.20 = 1.45$$

at the 5% level, t = 2 and 2.634 x 2 = 5.268

but 1.45 $<$ 5.268, and the difference found is not significant.

*score: 0.5" bruising = 4.

Table V. Experiment I. The comparative effects of bulk and box-handling on the firmness* of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	$Deviation^2$	B=box	Deviation −	Deviation +	$Deviation^2$
1	13.2		0.52	0.2704	12.2	0.085		0.007225
2	13.5		0.82	0.6724	12.1	0.185		0.034225
3	14.0		1.32	1.7424	13.0		0.715	0.511225
4	14.2		1.52	2.3104	12.5		0.215	0.046225
5	13.4		0.72	0.5184	12.4		0.115	0.013225
6	14.3		1.62	2.6244	12.3		0.015	0.000225
7	11.6	1.08		1.1664	13.5		1.215	1.476225
8	12.3	0.38		0.1444	12.0	0.285		0.081225
9	11.5	1.18		1.3924	11.7	0.585		0.342225
10	11.7	0.98		0.9604	12.2	0.085		0.007225
11	13.9		1.22	1.4884	12.7		0.415	0.172225
12	11.8	0.88		0.7744	12.4		0.115	0.013225
13	12.7		0.02	0.004	12.3		0.015	0.000225
14	12.5	0.18		0.0324	11.7	0.585		0.342225
15	11.4	1.28		1.6384	12.0	0.285		0.081225
16	11.8	0.88		0.7744	12.2	0.085		0.007225
17	12.2	0.48		0.2304	11.8	0.485		0.235225
18	11.7	0.98		0.9604	12.6		0.315	0.099225
19	13.2		0.52	0.2704	12.1	0.185		0.034225
20	12.7		0.02	0.0004	12.0	0.285		0.081225
Total	253.6	8.30	8.30	17.9720	245.7	3.135	3.135	3.585500
Mean	12.68 lbs				12.285 lbs			

$$S.D._A = \sqrt{\frac{17.9720}{19}} = 0.9725 \qquad S.D._B = \sqrt{\frac{3.5855}{19}} = 0.4344$$

$$E_A = \frac{0.9725}{\sqrt{20}} = 0.217 \qquad E_B = \frac{0.4344}{\sqrt{20}} = 0.097$$

$$E_D = \sqrt{(0.217)^2 + (0.097)^2} = 0.2376 \text{ lb}$$

$$D = 12.680 - 12.285 = 0.395 \text{ lb}$$

at 5% level, t = 2, and 0.2376 x 2 = 0.4752 lb

but $0.395 < 0.4752$; consequently, the difference is not significant.

*pressure-test reading in pounds.

Table VI. Experiment I. The comparative effects of bulk and box-handling on the sugar content on Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	$Deviation^2$	B=box	Deviation −	Deviation +	$Deviation^2$
1	12.6	0.995		0.990025	12.6	0.335		0.112225
2	14.2		0.605	0.366025	12.5	0.435		0.189225
3	14.0		0.405	0.164025	12.2	0.735		0.540225
4	13.6		0.005	0.000025	13.0		0.065	0.004225
5	13.2	0.395		0.156025	13.5		0.565	0.319225
6	14.0		0.405	0.164025	12.1	0.835		0.697225
7	13.5	0.095		0.009025	14.4		1.465	2.146225
8	14.2		0.605	0.366025	13.5		0.565	0.319225
9	13.2	0.395		0.156025	13.3		0.365	0.133225
10	12.1	1.495		2.235025	14.0		1.065	1.134225
11	15.0		1.405	1.974025	13.4		0.465	0.216225
12	12.1	1.495		2.235025	11.2	1.735		3.010225
13	13.9		0.305	0.093025	13.8		0.865	0.748225
14	14.1		0.505	0.255025	13.4		0.465	0.216225
15	13.8		0.205	0.042025	12.7	0.235		0.055225
16	13.9		0.305	0.093025	13.5		0.565	0.319225
17	13.1	0.495		0.245025	12.0	0.935		0.874225
18	13.3	0.295		0.087025	12.3	0.635		0.403225
19	14.2		0.605	0.366025	13.1		0.165	0.027225
20	13.9		0.305	0.093025	12.2	0.735		0.540225
Total	271.9	5.660	5.660	10.089500	258.7	6.615	6.615	12.005500

Mean 13.595 percent 12.935 percent

$S.D._A = \sqrt{\frac{10.0895}{19}} = 0.7287$ $S.D._B = \sqrt{\frac{12.0055}{19}} = 0.7949$

$E_A = \frac{0.7287}{\sqrt{20}} = 0.1629$ $E_B = \frac{0.7949}{\sqrt{20}} = 0.1777$

$E_D = \sqrt{(0.1629)^2 + (0.1777)^2} = 0.2410$

$D = 13.595 - 12.935 = 0.660$

at 5% level, t = 2 and 0.241 x 2 = 0.482

at 1% level, t = 2.58 and 0.241 x 2.58 = 0.62178

and $0.660 > 0.62178$. Consequently, the difference is highly significant.

Table VII*. Experiment II. The effects of bulk-handling on Yellow Newtown Apples.

Sample No	Apples No	weight before (gram)	weight after (gram)	weight lost (gram)	apples vol. (cc)	air-vol in can (cc)	CO_2%	CO_2%	CO_2%	CO_2 aver (%)	CO_2(mg /kg/hr	pressure (lbs)	sugar (%)	bruising
1	6	813.6	813.0	0.6	1017	3633	4.4	4.7	4.4	4.5	16.4	14.1	13.9	21
2	6	805.8	804.6	1.2	1007	3643	4.4	4.4	4.7	4.5	16.6	15.2	14.8	17
3	6	838.3	837.3	1.0	1048	3602	5.2	5.6	5.7	5.5	19.4	14.0	13.4	18
4	6	829.4	828.0	1.4	1037	3613	5.0	5.5	5.1	5.2	18.5	14.6	13.9	16
5	6	813.1	812.0	1.1	1016	3634	5.1	4.6	5.0	4.9	17.7	13.9	14.3	22
6	6	814.7	813.2	1.5	1018	3632	5.2	5.7	6.0	5.6	20.4	13.9	13.2	12
7	6	819.5	817.9	1.6	1024	3626	4.5	4.2	4.4	4.4	15.9	14.5	14.2	23
8	6	831.4	830.2	1.2	1039	3611	4.8	5.2	4.7	4.9	17.4	14.3	13.9	27
9	6	826.5	825.5	1.0	1033	3617	5.2	5.5	5.0	5.2	18.6	15.0	14.8	32
10	6	825.2	824.4	0.8	1032	3618	5.4	5.6	5.0	5.3	19.0	15.2	15.1	32
11	6	866.0	865.0	1.0	1083	3567	5.5	5.5	5.5	5.5	19.2	15.0	14.2	27
12	6	821.2	820.5	0.7	1027	3623	5.4	5.7	5.2	5.4	19.5	14.7	13.8	32
13	6	800.4	800.0	0.4	1001	3649	5.6	5.3	5.1	5.3	19.8	14.3	13.8	35
14	6	792.5	791.0	1.5	991	3659	5.4	5.7	5.2	5.4	20.4	13.8	13.5	23
15	6	828.9	827.1	1.8	1036	3614	5.8	5.6	5.6	5.7	20.3	13.9	13.7	42
16	6	820.6	818.9	1.7	1026	3624	5.0	5.0	4.9	5.0	18.1	14.8	14.2	31
17	6	835.8	833.9	1.9	1045	3605	5.7	5.6	5.0	5.4	19.0	13.9	14.0	24
18	6	837.3	836.0	1.3	1047	3603	5.8	5.4	5.8	5.7	19.9	14.4	14.0	30
19	6	801.9	800.2	1.7	1002	3648	5.9	5.1	5.0	5.3	19.7	14.9	14.3	25
20	6	810.5	810.0	0.5	1015	3635	5.1	5.4	5.2	5.2	19.1	14.6	14.4	34
Total	120	16,432.6	16,408.7	23.9							374.9	289.0	281.4	523
Mean	6			1.195							18.745	14.45	14.07	26.15

*Cont. on next page

Table VII (Cont.). Experiment II. The effects of field-box handling on Yellow Newtown Apples.

Sample No	Apples No	weight before (gram)	weight after (gram)	weight lost (gram)	apples vol. (cc)	air-vol in can (cc)	CO_2%	CO_2%	CO_2%	CO_2 aver. (%)	CO_2(mg/kg/hr	pressure (lbs)	sugar (%)	bruising
1	6	826.1	824.6	1.5	1032	3618	8.3	8.0	8.0	8.1	29.2	15.2	14.3	45
2	6	803.8	802.4	1.4	1005	3646	8.0	7.9	8.4	8.1	30.1	14.7	14.6	35
3	6	837.9	835.9	2.0	1047	3603	8.2	9.0	9.8	9.0	31.7	14.7	13.8	32
4	6	828.7	826.7	2.0	1036	3614	8.5	8.8	8.9	8.7	31.1	13.8	13.6	45
5	6	826.2	824.8	1.4	1033	3617	8.7	9.0	9.0	8.9	31.9	14.3	13.5	28
6	6	805.9	804.2	1.7	1007	3643	8.3	8.3	8.1	8.2	30.3	14.0	13.2	47
7	6	813.5	812.2	1.3	1017	3533	9.0	8.5	8.0	8.5	31.1	13.4	13.4	37
8	6	819.9	818.1	1.8	1024	3626	8.9	8.2	7.6	8.2	29.8	13.2	13.6	36
9	6	822.2	820.3	1.9	1028	3622	9.4	8.6	8.2	8.7	31.4	13.3	13.0	32
10	6	809.8	808.4	1.4	1012	3638	9.2	8.4	8.2	8.6	31.6	13.7	12.9	38
11	6	824.4	821.9	2.5	1026	3624	9.6	8.5	8.4	8.8	31.7	14.1	13.2	34
12	6	817.9	816.2	1.7	1021	3629	9.1	8.3	9.9	9.1	33.2	13.4	13.5	47
13	6	825.5	824.2	1.3	1032	3618	9.3	8.4	8.6	8.8	31.7	14.2	13.4	38
14	6	838.8	836.6	2.2	1049	3601	9.4	8.1	8.3	8.6	31.5	14.5	14.0	38
15	6	832.3	830.9	1.4	1040	3610	8.9	8.4	8.1	8.5	30.2	14.8	14.2	36
16	6	829.8	828.1	1.7	1037	3613	8.9	8.5	9.0	8.8	31.2	14.0	13.4	40
17	6	830.4	828.4	2.0	1038	3612	9.1	9.3	9.4	9.3	33.1	13.9	14.0	29
18	6	809.0	807.3	1.7	1011	3639	8.5	8.9	8.8	8.7	32.1	13.3	13.0	30
19	6	810.6	808.8	1.8	1013	3637	8.6	8.1	8.3	8.3	30.5	13.6	12.7	47
20	6	821.6	819.7	1.9	1027	3623	9.0	8.6	8.5	8.7	31.5	14.1	13.3	43
Total	120	16434.3	16,399.7	34.6							624.9	280.2	270.6	757
Mean	6			1.73							31.245	14.01	13.53	37.85

Table VIII. Experiment II. The comparative effects of bulk and box-handling on the shrivelling* of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	$Deviation^2$	B=box	Deviation −	Deviation +	$Deviation^2$
1	0.6	0.595		0.354025	1.5	0.23		0.0529
2	1.2		0.005	0.000025	1.4	0.33		0.1089
3	1.0	0.195		0.038025	2.0		0.27	0.0729
4	1.4		0.205	0.042025	2.0		0.27	0.0729
5	1.1	0.095		0.009025	1.4	0.33		0.1089
6	1.5		0.305	0.093025	1.7	0.03		0.0009
7	1.6		0.405	0.164025	1.3	0.43		0.1849
8	1.2		0.005	0.000025	1.8		0.07	0.0049
9	1.0	0.195		0.038025	1.9		0.17	0.0289
10	0.8	0.395		0.156025	1.4	1.33		0.1089
11	1.0	0.195		0.038025	2.5		0.77	0.5929
12	0.7	0.495		0.245025	1.7	0.03		0.0009
13	0.4	0.795		0.632025	1.3	0.43		0.1849
14	1.5		0.305	0.093025	2.2		0.47	0.2209
15	1.8		0.605	0.366025	1.4	0.33		0.1089
16	1.7		0.505	0.255025	1.7	0.03		0.0009
17	1.9		0.705	0.497025	2.0		0.27	0.0729
18	1.3		0.105	0.011025	1.7	0.03		0.0009
19	1.7		0.505	0.255025	1.8		0.07	0.0049
20	0.5	0.695		0.483025	1.9		0.17	0.0289
Total	23.9	3.655	3.655	3.769500	34.6	2.53	2.53	1.9620
Mean	1.195				1.73			

$$S.D._A = \sqrt{\frac{3.7695}{19}} = 0.4454 \qquad S.D._B = \sqrt{\frac{1.9620}{19}} = 0.3213$$

$$E_A = \frac{0.4454}{\sqrt{20}} = 0.099 \qquad E_B = \frac{0.3213}{\sqrt{20}} = 0.071$$

$$E_D = \sqrt{(0.099)^2 + (0.071)^2} = 0.1218 \text{ gram}$$

D of means = 1.730 − 1.195 = 0.535 gram

at the 5% level, t = 2 and 0.1218 x 2 = 0.2436

at the 1% level, t = 2.58 and 0.1218 x 2.58 = 0.314244

and 0.535 $>$ 0.314244; hence, the difference is highly significant.

*weight in grams lost by each sample over a 24-hour period.

Table IX. Experiment II. The comparative effects of bulk and box-handling on the respiration rate* of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	Deviation^2	B=box	Deviation −	Deviation +	Deviation^2
1	16.4	2.345		5.508025	29.2	2.045		4.182025
2	16.6	2.145		4.601025	30.1	1.145		1.311025
3	19.4		0.655	0.429025	31.7		0.455	0.207025
4	18.5	0.245		0.060025	31.1	0.145		0.021025
5	17.7	1.045		1.092025	31.9		0.655	0.429025
6	20.4		1.655	2.739025	30.3	0.945		0.893025
7	15.9	2.845		8.094025	31.1	0.145		0.021025
8	17.4	1.345		1.809025	29.8	1.445		2.088025
9	18.6	0.145		0.021025	31.4		0.155	0.024025
10	19.0		0.255	0.065025	31.6		0.355	0.126025
11	19.2		0.455	0.207025	31.7		0.455	0.207025
12	19.5		0.755	0.570025	33.2		1.955	3.822025
13	19.8		1.055	1,113025	31.7		0.455	0.207025
14	20.4		1.655	2.739025	31.5		0.255	0.065025
15	20.3		1.555	2.418025	30.2	1.045		1,092025
16	18.1	0.645		0.416025	31.2	0.045		0.002025
17	19.0		0.255	0.065025	33.1		1.855	3.441025
18	19.9		1.155	1.334025	32.1		0.855	0.731025
19	19.7		0.955	0.912025	30.5	0.745		0.555025
20	19.1		0.355	0.126025	31.5		0.255	0.065025
Total	374.9	10.760	10.760	34.318500	624.9	7.705	7.705	19.489500
Mean	18,745				31.245			

$$S.D._A = \sqrt{\frac{34.3185}{19}} = 1.343 \qquad S.D._B = \sqrt{\frac{19.4895}{19}} = 1.012$$

$$E_A = \frac{1.343}{\sqrt{20}} = 0.300 \qquad E_B = \frac{1.012}{\sqrt{20}} = 0.226$$

$$E_D = \sqrt{(0.300)^2 + (0.226)^2} = 0.375 \text{ mg}$$

D of means = 31.245 − 18,745 = 12.500 mg

at 5% level, t = 2 and 0.375 x 2 = 0.750

at 1% level, t = 2.58 and 0.375 x 2.58 = 0.9675

and 12.5 $>$ 0.9675; hence, the difference is highly significant.

*milligrams of CO_2 evolved per kilogram of fruit and per hour.

Table X. Experiment II. The comparative effects of bulk and box-handling on the bruising* of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	Deviation^2	B=box	Deviation −	Deviation +	Deviation^2
1	21	5.15		26.5225	45		7.15	51.1225
2	17	9.15		83.7225	35	2.85		8.1225
3	18	8.15		66.4225	32	5.85		34.2225
4	16	10.15		103.0225	45		7.15	51.1225
5	22	4.15		17.2225	28	9.85		97.0225
6	12	14.15		200.2225	47		9.15	83.7225
7	23	3.15		9.9225	37	0.85		0.7225
8	27		0.85	0.7225	36	1.85		3.4225
9	32		5.85	34.2225	32	5.85		34.2225
10	32		5.85	34.2225	38		0.15	0.0225
11	27		0.85	0.7225	34	3.85		14.8225
12	32		5.85	34.2225	47		9.15	83.7225
13	35		8.85	78.3225	38		0.15	0.0225
14	23	3.15		9.9225	38		0.15	0.0225
15	42		15.85	251.2225	36	1.85		3.4225
16	31		4.85	23.5225	40		2.15	4.6225
17	24	2.15		4.6225	29	8.85		78.3225
18	30		3.85	14.8225	30	7.85		61.6225
19	25	1.15		1.3225	47		9.15	83.7225
20	34		7.85	61.6225	43		5.15	26.5225
Total	523	60.50	60.50	1056.5500	757	49.50	49.50	720.5500
Mean	26.15				37.85			

$S.D._A = \sqrt{\frac{1056.55}{19}} = 7.457$ $S.D._B = \sqrt{\frac{720.55}{19}} = 6.158$

$E_A = \frac{7,457}{\sqrt{20}} = 1.66$ $E_B = \frac{6.158}{\sqrt{20}} = 1.37$

$E_D = \sqrt{(1.66)^2 + (1.37)^2} = 2.152$

D of means = 37.85 - 26.15 = 11.70

at 5% level, t = 2 and 2.152 x 2 = 4.304

at 1% level, t = 2.58 and 2.152 x 2.58 = 5.55216

and 11.70   5.55216; consequently, the difference is highly significant.

*score: 0.5" bruising = 4.

Table XI. Experiment II. The comparative effects of bulk and box-handling on the firmness*of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	Deviation²	B=box	Deviation −	Deviation +	Deviation²
1	14.1	0.35		0.1225	15.2		1.19	1.4161
2	15.2		0.75	0.5626	14.7		0.69	0.4761
3	14.0	0.45		0.2025	14.7		0.69	0.4761
4	14.6		0.15	0.0225	13.8	0.21		0.0441
5	13.9	0.55		0.3025	14.3		0.29	0.0841
6	13.9	0.55		0.3025	14.0	0.01		0.0001
7	14.5		0.05	0.0025	13.4	0.61		0.3721
8	14.3	0.15		0.0225	13.2	0.81		0.6561
9	15.0		0.55	0.3025	13.3	0.71		0.5041
10	15.2		0.75	0.5625	13.7	0.31		0.0961
11	15.0		0.55	0.3025	14.1		0.09	0.0081
12	14.7		0.35	0.0625	13.4	0.61		0.3721
13	14.3	0.15		0.0225	14.2		0.19	0.0361
14	13.8	0.65		0.4225	14.5		0.49	0.2401
15	13.9	0.55		0.3025	14.8		0.79	0.6241
16	14.8		0.35	0.1225	14.0	0.01		0.0001
17	13.9	0.55		0.3025	13.9	0.11		0.0121
18	14.4	0.05		0.0025	13.3	0.71		0.5041
19	14.9		0.45	0.2025	13.6	0.41		0.1681
20	14.6		0.15	0.0225	14.1		0.09	0.0081
Total	289.0	4.00	4.00	4.1700	280.2	4.51	4.51	6.0989
Mean	14.45				14.01			

$SD_A = \sqrt{\frac{4.170}{19}} = 0.4684$ $\qquad$ $S.D._B = \sqrt{\frac{6.098}{19}} = 0.6112$

$E_A = \frac{0.4684}{\sqrt{20}} = 0.104$ $\qquad$ $E_B = \frac{0.6112}{\sqrt{20}} = 0.136$

$E_D = \sqrt{(0.104)^2 + (0.136)^2} = 0.171$

D of means = 14.45 - 14.01 = 0.44

at the 5% level, t = 2 and 0.171 x 2 = 0.342

at the 1% level, t = 2.58 and 0.171 x 2.58 = 0.44118

but 0.44 > 0.342; hence, the difference is significant.

*pressure-test reading in pounds.

Table XII. Experiment II. The comparative effects of bulk and box-handling on the sugar content of Yellow Newtown Apples.

Sample	A=bulk	Deviation −	Deviation +	$Deviation^2$	B=box	Deviation −	Deviation +	$Deviation^2$
1	13.9	0.17		0.0289	14.3		0.77	0.5929
2	14.8		0.73	0.5329	14.6		1.07	1.1449
3	13.4	0.67		0.4489	13.8		0.27	0.0729
4	13.9	0.17		0.0289	13.6		0.07	0.0049
5	14.3		0.23	0.0529	13.5	0.03		0.0009
6	13.2	0.87		0.7569	13.2	0.33		0.1089
7	14.2		0.13	0.0169	13.4	0.13		0.0169
8	13.9	0.17		0.0289	13.6		0.07	0.0049
9	14.8		0.73	0.5329	13.0	0.53		0.2809
10	15.1		1.03	1.0609	12.9	0.63		0.3969
11	14.2		0.13	0.0169	13.2	0.33		0.1089
12	13.8	0.27		0.0729	13.5	0.03		0.0009
13	13.8	0.27		0.0729	13.4	0.13		0.0169
14	13.5	0.57		0.3249	14.0		0.47	0.2209
15	13.7	0.37		0.1369	14.2		0.67	0.4489
16	14.2		0.13	0.0169	13.4	0.13		0.0169
17	14.0	0.07		0.0049	14.0		0.47	0.2209
18	14.0	0.07		0.0049	13.0	0.53		0.2809
19	14.3		0.23	0.0529	12.7	0.83		0.6889
20	14.4		0.33	0.1089	13.3	0.23		0.0529
Total	281.4	3.67	3.67	4.3020	270.6	3.86	3.86	4.6820
Mean	14.07				13.53			

$$S.D._A = \sqrt{\frac{4.302}{19}} = 0.4758 \qquad S.D._B = \sqrt{\frac{4.682}{19}} = 0.4964$$

$$E_A = \frac{0.4758}{\sqrt{20}} = 0.1063 \qquad E_B = \frac{0.4964}{\sqrt{20}} = 0.1109$$

$$E_D = \sqrt{(0.1063)^2 + (0.1109)^2} = 0.1536$$

D of means = 14.07 - 13.53 = 0.54%

at 5% level, t = 2 and 0.1536 x 2 = 0.3072

at 1% level, t = 2.58 and 0.1536 x 2.58 = 0.396288

and $0.54 > 0.396288$; consequently, the difference is highly significant.

Table XIII. Experiment III. The comparative effects of different types of packaging on shrivelling, respiration rate, firmness and sugar content of McIntosh Apples.

Sample No	Apples No	Type of packaging	weight before (gram)	weight after (gram)	weight lost (gram)	Apple vol (cc)	Air vol (cc)	CO_2%	CO_2%	CO_2%	CO_2% average	mg CO_2 kg/hr	Pressure (lbs)	Sugar (%)
1	6	none (check)	826.1	824.2	1.9	1053	3597	7.2	7.2	4.9	6.4	22.8	8.4	12.2
2	6	none (check)	875.3	873.0	2.3	1091	3559	8.0	11.7	9.2	9.6	32.0	8.1	11.7
Average					2.1							27.4	8.25	11.95
1	6	wax	1044.3	1043.1	1.2	1303	3347	8.4	7.3	5.2	6.9	22.1	8.1	12.4
2	6	wax	1030.9	1029.9	1.0	1286	3364	8.2	10.3	7.4	8.6	23.6	8.6	12.5
Average					1.1							22.85	8.35	12.45
1	6	Oiled Paper	930.6	928.8	1.8	1161	3489	7.2	7.1	5.9	6.7	20.6	8.4	11.6
2	6	Oiled Paper	951.4	949.9	1.5	1187	3463	8.3	10.1	9.4	9.3	27.7	8.0	12.2
Average					1.65							24.15	8.20	11.90
1	6	Polytene Bag	924.2	923.4	0.8	1156	3494	2.5	3.2	4.0	3.2	9.9	9.0	13.3
2	6	Polytene Bag	946.7	945.7	1.0	1183	3467	4.1	5.2	4.2	4.5	13.5	9.2	12.9
Average					0.9							11.70	9.10	13.10

The CO_2 contained in the sealed polyethylene liners averaged 3.6% in sample 2 and 4.4% in sample 1.

Polyethylene