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Apple Juice, Preparation and Preservation
Michigan State University Agricultural Experiment Station
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Roy E. Marshall
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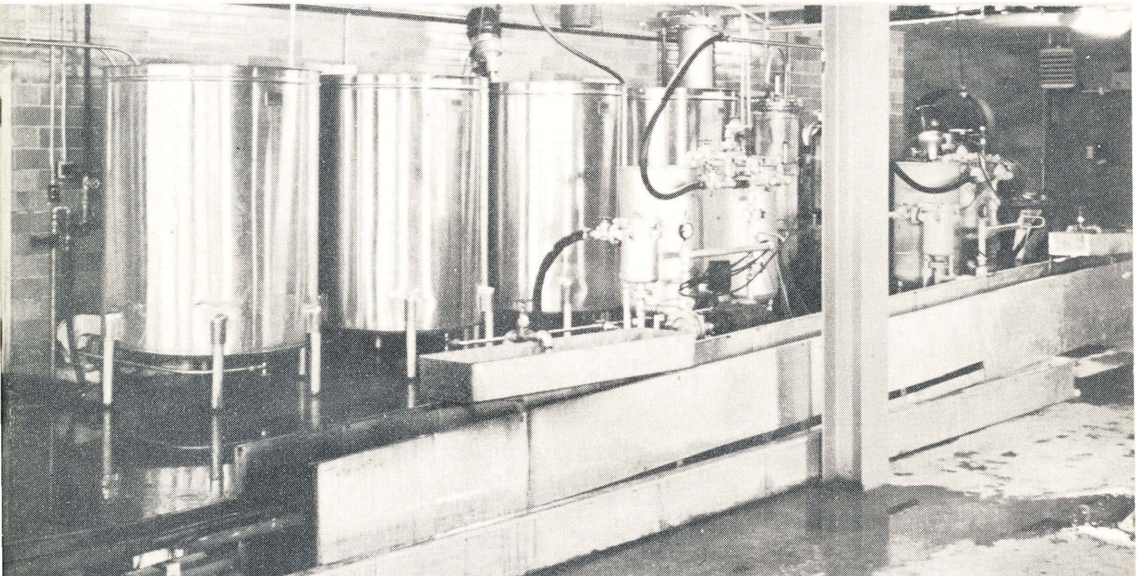
CIRCULAR BULLETIN 206 (2nd Printing) APRIL 1952

APPLE JUICE

Preparation and Preservation

By ROY E. MARSHALL

A portion of the interior of a modern plant for processing apple juice. (For details, see page 2.)



MICHIGAN STATE COLLEGE :: AGRICULTURAL EXPERIMENT STATION
EAST LANSING

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(Title page illustration)

In the rear of the fourth tank are two heat exchangers for flash heating and flash cooling juice that is to be clarified with bentonite in the third and fourth stainless steel tanks. The two filters, on either side of the post, deliver the filtered juice into one of the two tanks in the foreground. The spinner cooler in the foreground is designed for cooling the filled cans. Flash pasteurization and can filling and sealing operations take place in an area to the left of the picture, and labeling and casing in an area to the right of the picture.

Apple Juice Preparation and Preservation

By ROY E. MARSHALL

America has become definitely "juice conscious" during recent years. The commercial production of tomato juice began in 1928, and some fruit juices, principally pineapple and grapefruit, were packed in commercial quantities within the next 2 or 3 years. During the decade beginning with 1930, improved methods were developed for the processing of citrus juices and the subsequent growth of this industry was phenomenal, as indicated in Table 1 and Fig. 1. During the 10-year period beginning with 1935, the volume of fruit juices, including tomato juice, packed in the United States increased nearly five-fold, until in 1944 there was available more than one-half case per capita of the six commercially processed fruit juices listed in Table 1. In addition, substantial quantities of grape, prune, berry and certain vegetable juices were processed in commercial plants. Thus, Americans are consuming in liquid form a substantial proportion of the fruits and vegetables that they formerly purchased in the form of raw products.

DEVELOPMENT OF THE APPLE JUICE INDUSTRY

The processing of unfermented apple juice has been attempted many times in various parts of the world, but until recent years every attempt at processing on a commercial scale ended in failure. The principal reason for such failure was that the method commonly and satisfactorily employed for such a product as grape juice proved unsatisfactory for apple juice. It imparted a "pasteurized," "cooked," or "apple sauce" taste that consumers did not like. Consequently, packers were not able to develop a volume of business that would justify operation of commercial plants until methods of processing were developed that retained the distinctive flavor and quality of non-processed apple juice.

The first pack of flash-pasteurized apple juice was made in 1937, when some 70,000 cases were packed in Michigan. Figure 2 shows that the apple juice pack increased each successive year in Michigan until 1941, when more than one-half million cases were packed. During the years 1937 to 1940, inclusive, most of the apple juice packed in the United States was produced in Michigan; thus, Michigan assumed the early leadership in the development of the processed apple juice industry.

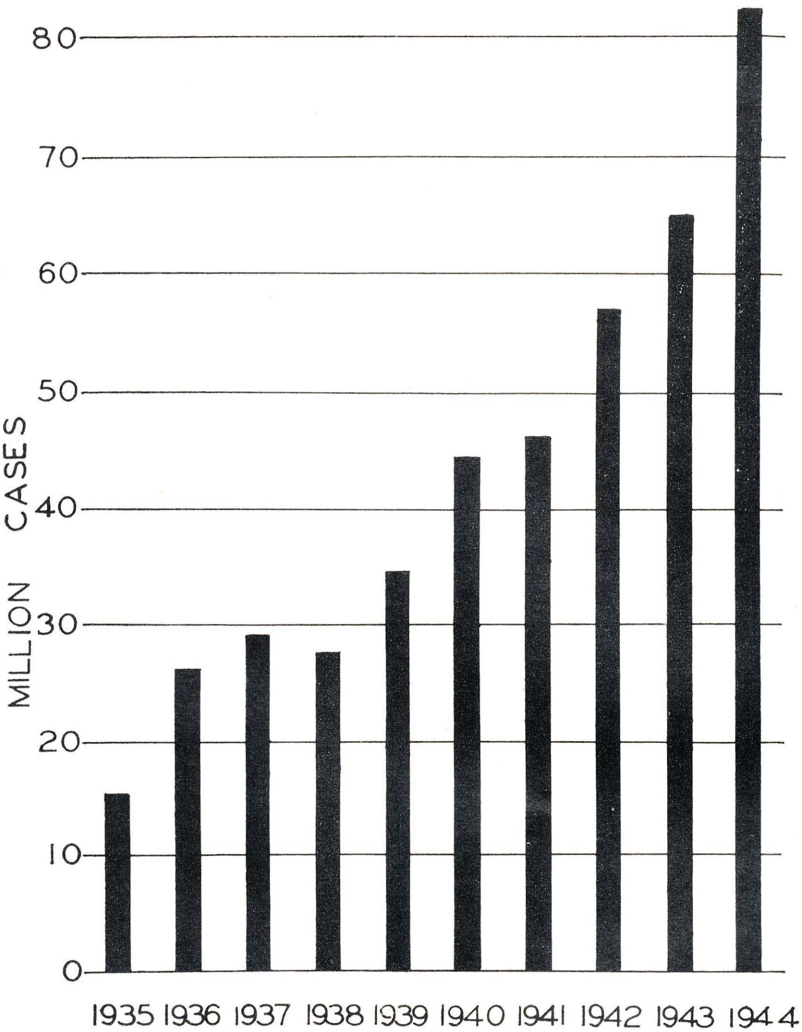

Fig. 1. The pack of processed fruit juices for the United States increased 430 percent in a decade.

The tin allocation for fruits and vegetables during World War II did not permit packing apple juice in tin cans, and it was, therefore, necessary to convert most of the apple juice to glass packing in 1942. This resulted in a probable decrease of some 200,000 cases of the potential pack in Michigan in 1942 and possibly as much as 400,000 to 600,000 cases for the United States. It is also probable that the abnormally high prices that prevailed for apples during World War II years had a depressing effect on the normal growth of the apple juice industry. Despite the combined effects of the tin allocation order and the high prices for the raw product, production of juice from the 1944 crop of apples amounted to 563,000 cases in Michigan and 2,851,000 cases for the United States (Fig. 2). This means that more than one-half million bushels of small, poorly colored, blemished, or unsymmetrical, but strictly wholesome apples (about 7 percent of the commercial crop) were converted to processed apple juice in Michigan, and that the volume converted to apple juice for the United States exceeded two and one-half million bushels.

Figure 1 and Table 1 show that there is a very definite and rapidly growing demand for processed fruit juices. There is evidence that the demand for apple juice is developing at a similar rate. Processors of quality apple juice state that they have had to limit sales of the packs

TABLE 1—*Fruit juice packs in United States 1939-1949, in thousands of actual cases.**

	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949
Apple juice.....	393	506	1,726	1,645	1,740	2,851	1,316	3,524	1,181	1,181	2,592
Grapefruit juice.	9,657	14,071	11,051	20,061	22,637	19,261	22,483	15,173	14,869	12,803	10,795
Orange juice....	3,578	4,012	4,406	2,703	7,372	18,425	19,397	17,135	23,993	18,039	17,667
Blended citrus juice.........	1,301	2,285	2,043	3,108	5,563	7,016	11,800	9,076	10,568	9,457	6,492
Pineapple juice..	8,551	11,285	8,721	8,782	8,230	7,954	8,671	8,207	8,890	10,043	10,405
Tomato juice....	11,091	12,414	19,046	20,738	19,252	26,487	24,553	30,525	16,880	23,701	20,560
Total....	34,571	44,573	45,993	57,037	64,794	81,994	88,220	83,640	76,381	75,224	68,511

*The data in Table 1 show actual cases packed. Packs consisted of containers and cases of various sizes. To convert the packs to the equivalents of 12 one-quart containers per case (3 gallons), the fruit juice figures should be increased 3 to 5 percent and the tomato juice packs by approximately 12 percent. Thus, the grand total pack for the 1944 crops is equivalent to approximately 80,000,000 cases of 12 one-quart containers.

made from 1944 and 1945 apple crops to distributors, even though no promotional campaign has been in existence since the beginning of World War II.

Filtered apple juice has eye appeal superior to that of any of the big volume juices and it has a distinctive flavor and a high quality. It possesses most of the healthful properties of the apple and, under normal conditions, can be served at a cost comparable to that of other fruit juices.

The Michigan apple industry is definitely interested in the development of outlets that will convert at least one-third of its seven and one-half million bushel commercial crop into apple products at a reasonable return to the grower. Such a program will result in a higher level of quality and better prices for fresh fruit. A substantial portion of the apples that are to be processed may be made into apple juice provided high quality is maintained by all plants and provided a reasonable amount of sales promotion is maintained. Whether apple juice will account for the utilization of one million or one and one-half million bushels of Michigan-grown apples annually within the next four or five years depends largely upon the wholesomeness of the apples delivered to the juice plants and the care exercised in processing the juice. The recorded development of the juice industry in general, and the apple juice business in particular, shows that the consuming public will utilize quality apple juice in large volume and at a price that will make a good return to the grower and the processor. Thus, the apple juice industry in Michigan, as well as in the United States, appears to be in a very favorable position for immediate and rapid expansion.

APPLE VARIETIES AND BLENDING

A processed product is never of better quality than the raw product from which it is made. If modern processing methods are followed carefully, the quality of the raw product is the most important factor in determining the quality of apple juice. This means a proper blending of varieties of apples that are well matured, properly ripened, and free from decay and insect infestation.

The "United States Standards for Grades of Canned and Bottled Apple Juice" specify that "U. S. Fancy Grade juice tests not less than 11.5 degrees Brix; contains not less than 0.75 percent of acid calculated as malic acid"; and Arengo-Jones (2) states that the fresh juice that is to be processed should test approximately as follows: specific gravity, 1.055; acid by volume as malic acid, 0.5 to 0.6 percent; tannin by volume as tannic acid, 0.06 to 0.1 percent. It might seem that any variety of apple yielding a juice that meets these specifications could be used alone to make a high quality juice, but this does not seem to be the case, for most investigators state that a blend of juices from several varieties is preferable to the juice from any single variety.

Caldwell (4) shows that the chemical composition of juice from most varieties of apples picked "market ripe" varies from season to season. For example, the following ranges in composition were found for the Baldwin variety harvested for the years 1920 to 1925, inclusive: total sugar, 10.11 percent in 1920 to 14.96 percent in 1923; malic acid, 0.424 percent in 1925 to 0.635 percent in 1923; tannin, 0.0259 percent

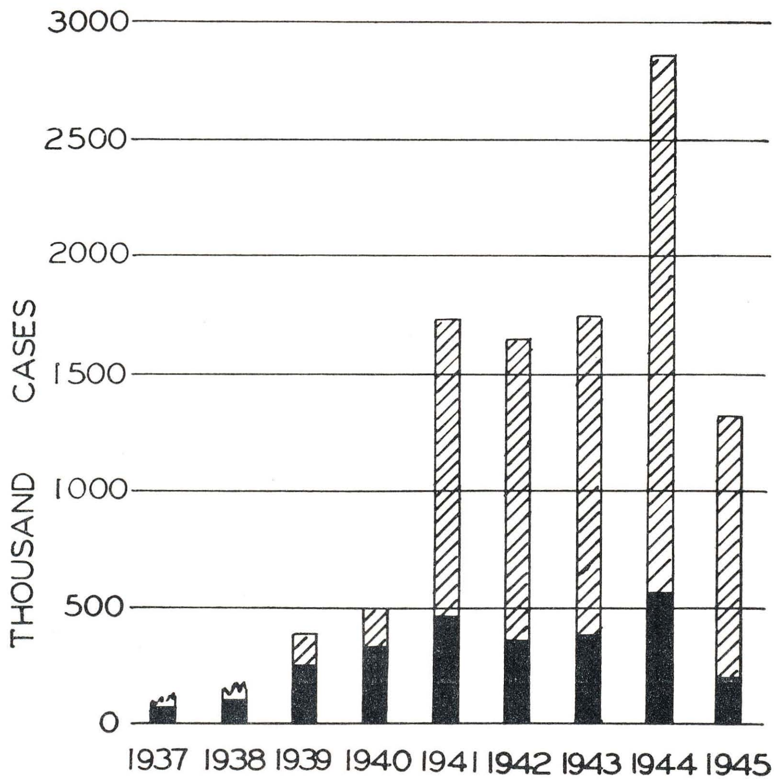

Fig. 2. The full-length of the bars indicates the volume of processed apple juice packed in the United States, and the solid portions, the pack for Michigan. The first commercial pack of flash-pasteurized apple juice was made in Michigan in 1937.

TABLE 2—*Composition of apple juice from eight varieties of apples, with the varieties arranged in descending order of rating for quality of juice. Compiled from a table by Clague and Fellers (7).*

Variety	Degrees Brix		Total acid in percent		Tannin in percent	
	1933	1944	1933	1944	1933	1944
Roxbury Russet	15.5	16.0	0.61	0.67	0.07	0.06
Baldwin	14.1	11.8	0.56	0.48	0.08	0.06
Northern Spy	11.8	12.0	0.48	0.49	0.08	0.08
R. I. Greening	11.2	12.0	0.44	0.47	0.04	0.07
McIntosh	12.2	11.5	0.41	0.48	——	0.08
Ben Davis	10.9	11.5	0.33	0.43	0.05	0.06
King	12.5	12.9	0.40	0.53	0.04	0.07
Wealthy	9.8	11.5	0.57	0.61	0.05	0.05

in 1924 to 0.060 percent in 1925. The calculated total sugar-acid ratio ranged from approximately 16 : 1 in 1920 to 27 : 1 in 1924.

The varieties listed in Table 2, from a table by Clague and Fellers (7) are arranged in order of their juice-making qualities. These data also show that considerable variation exists in chemical composition for juice from the same variety produced in different years. Perhaps of greatest interest, however, is the fact that there is no consistent relationship between chemical composition and quality of the juice. For example, both Roxbury Russet (ranking first) and King (ranking seventh) produced juice with high Brix readings and Roxbury Russet and Wealthy (ranking last) were the two varieties with the highest percentage of acid. There is some indication of a relationship between tannin content and quality, but the data are hardly consistent enough to warrant conclusions.

Fabian and Marshall (9) classified varieties of apples into five groups, as follows: acid to sub-acid, sub-acid to mild, aromatic, astringent, and neutral. They suggest the percentages of apples from varieties of each group that may be combined to make satisfactory blends. This plan is hardly practical in Michigan because all varieties now recommended for commercial plantings belong to the sub-acid to mild and the aromatic groups.

All investigators agree that the quality of apple juice may be improved by blending of varieties, but even though the combined efforts of these investigators represent hundreds of observations on blends, most of them conclude that it is not possible to provide an infallible rule for blending. Mottern and associates (19) examined 60 samples of apple juice packed by 52 processors from apples grown in 1940 and concluded that it is futile to recommend a particular blend because juice must be made from the varieties that are available. Most of the better samples had an acidity of about 0.5 percent, but a wide range of Brix readings was found among them.

Aromatic varieties, such as McIntosh and Delicious, are low in acidity and should, therefore, be blended with such tart apples as Rhode Island Greening or Baldwin, according to Tressler and Pederson (25). Arengo-Jones (2), working with Canadian apples, makes several suggestions, including these: 25 percent McIntosh can be used to give flavor to juice made from such varieties as Stark, Northern Spy,

Photo: Reynolds Brothers, Sturgeon Bay, Wis.

Fig. 3. These outdoor wooden bins are 16 feet square, 2 feet deep at the outer edges where apples are received from the trucks, and 5 feet deep along the inside where the apples are fed through gates into a flume, to be floated to the mechanical elevator in the background. Varieties are segregated in the bins and fed into the flume simultaneously from several bins to produce a blended juice.

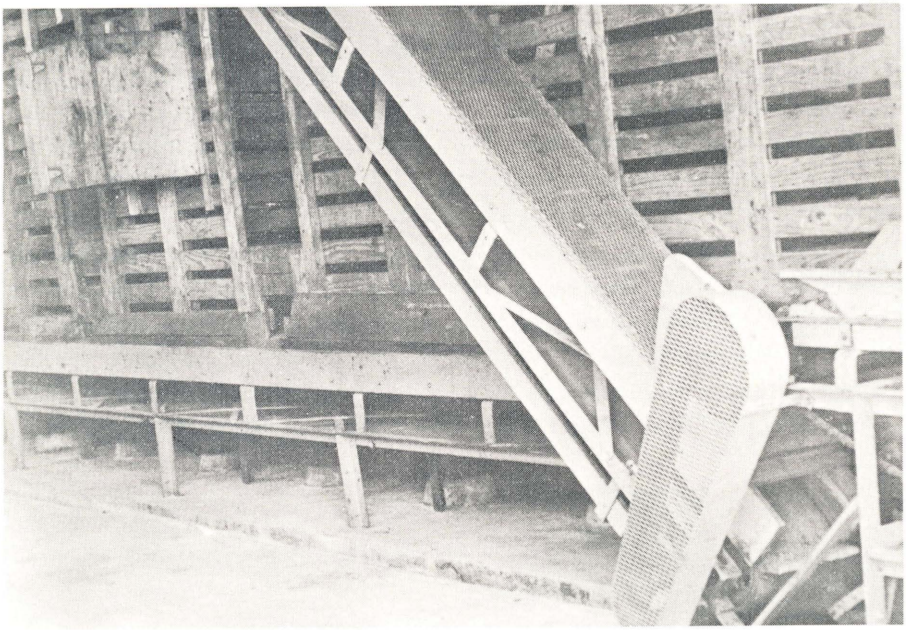

Fig. 4. Apples delivered to this plant pass over a leaf eliminator (lower right) and are then delivered to slatted bins by a motor-driven elevator and by conveyors. The horizontal conveyor at the base of the bins delivers apples from the bins to grinder and press room.

or Ben Davis; Baldwin alone makes good juice, but may be improved by adding 25-percent McIntosh; equal parts of Golden Russet and Northern Spy make a very aromatic juice; Wealthy or Snow blend well with McIntosh; Delicious and Rome make a satisfactory combination.

Our experience of some 15 years is based largely on the blending of varieties that have been available in the largest quantities. They include principally such varieties as Baldwin, Delicious, Grimes, McIntosh, Northern Spy, Rhode Island Greening, and Stayman. The juices of best quality have varied considerably in variety blends. In most cases four or five varieties have been blended in various proportions. Most of the combinations have included Northern Spy and Grimes, partly because of the proportions of the crop of the former that are under-colored and of the latter that are too small to be marketed as fresh fruit, and partly because the flavor imparted by a small proportion of Grimes is desirable. A typical blend of some of the juices having the best quality would be: Northern Spy, 20 to 40 percent; Grimes, 10 to 20 percent; Baldwin, 10 to 30 percent; and 10 to 20 percent of one or more of such varieties as Stayman, McIntosh, Delicious, or Rhode Island Greening. A liberal supply of Jonathan, one of the leading varieties in Michigan, has not been available, but the experience of commercial packers indicates that it may be blended with three or four of the other important varieties.

Duchess does not make a satisfactory variety to blend with others for apple juice. Even when the proportion of Duchess juice constituted only 12 percent of total, the resulting juices were rated as having poor flavor.

On the whole, observations indicate that any combination of four or five commercial varieties that are available in a fully ripened condition after early October may be used to make a satisfactory blend of juice. This means that the variety combination used in October

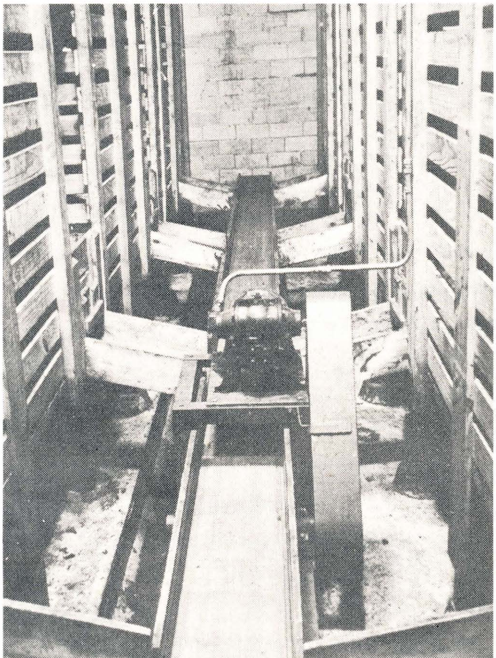

Fig. 5. Four slatted bins on either side of this motor-driven conveyor belt enable the operator to supply proper blends of varieties to the grinder and press room.

may be entirely different from that employed in December and that the juice made at different times may be expected to be of rather uniform quality, provided at least four varieties are used in the blend.

WASHING AND SORTING

Fresh fruit packing houses usually grade and pack only one or perhaps two varieties at a time. Hence, it becomes necessary to accumulate considerable quantities of juice stock apples until such time as three, four, or five varieties are available for blending as juice stock. Where large volumes of apples of each variety are involved, the most satisfactory method of handling is to hold the juice stock in slatted orchard crates in cold storage, or in common storage if cold storage is not available. The crates of apples can be conveyed to the juice plant later in suitable proportions of each variety, without an undue amount of labor.

Some apple juice plants have a number of slatted bins, each holding 1,000 to 1,500 bushels. These bins may be constructed in a double row with an alleyway some 3 to 4 feet in width between them, through which is located a concrete or half-tile water flume or a mechanical conveyor to transport the apples from each of several bins simultaneously to the grinding and pressing operation. These bins may have floors that slope toward the alleyway and water flume and an adjustable gate just above the floor line on the alley side of the bins that will permit unloading the bins with a minimum of effort. A pump and a pipe line are essential to return the flume water from the exit end of the flume to the opposite end for re-circulation. Such a bin arrangement permits separation of varieties during temporary storage and subsequent mixing in the desired proportions for grinding.

Apples that are to be made into juice should be ripe, but not overripe, sound, and clean. It is therefore necessary to sort the apples, as they move toward the grinder, to remove any fruits that show evidences of decay or insect infestation. Even a very few small soft rots will impart a musty taste to a large volume of apple juice. A satisfactory arrangement for sorting may be made by having the apples pass over a roll inspection conveyor some 4 to 6 feet in length. The rolls serve to turn the apples continuously so that they may be thoroughly inspected as they move along the conveying line.

All apples used for making apple juice must be washed. If the juice stock comes from a modern fruit packing house, they will have

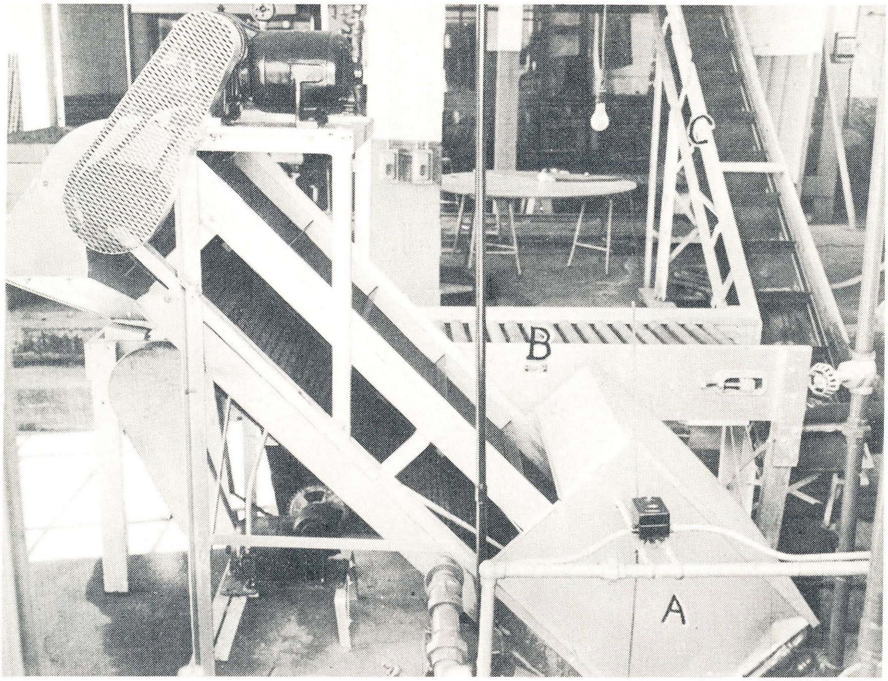

Fig. 6. Strong sprays of water, directed from above and below the metal elevator belt, wash the apples at A. The sorting is done as the apples are being turned continuously on the belt of wooden rolls shown at B. The apples are then conveyed to the grinder by the elevator at C.

been washed or brushed prior to the time of removal of the juice stock. Rewashing is usually not necessary for such stock. Even though the apples have been brushed in the packing house, they must undergo subsequent washing to meet federal requirements for a juice stock.

It is seldom necessary to provide a washing treatment severe enough to remove spray residues. The tolerances are now high enough to permit most apples grown in Michigan to be marketed without resorting to washing or brushing treatments designed to remove spray residue. Furthermore, our investigations indicate that most of the spray residue remains in the pomace. Even before the spray residue tolerances were raised to their present levels, analyses made of apple juice by the Michigan Agricultural Experiment Station failed to show enough arsenic or lead to make residue removal from the raw product necessary. There is also evidence that most of the DDT residue on the apples at harvest time remains in the pomace rather than the juice. Whether there is enough of this material in apple pomace to make it

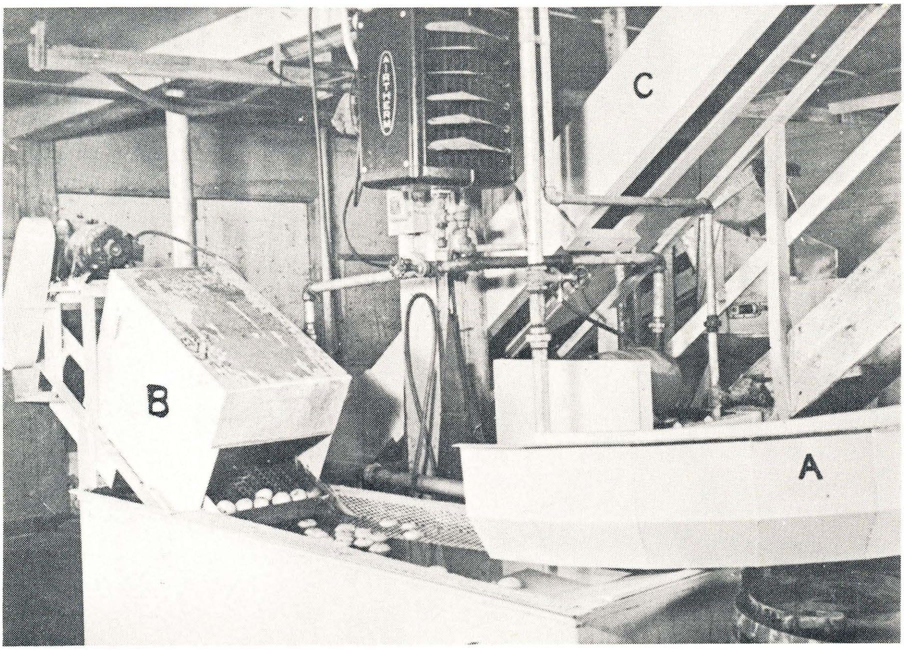

Fig. 7. In this plant, previously sorted apples are delivered to the soaker tank by the flume at A and then pass through the hooded washer at B, which is equipped with spray nozzles located both above and below the metal elevator belt. The conveyor at C elevates the apples to the grinder located on the second floor.

inadvisable to use the pomace for food products is not known at this writing.

Washing juice stock apples may usually be accomplished by passing the fruit through a flotation type washer, or by immersion in a tank or flume where the water is agitated, followed by a rinsing spray as the apples make their ascent up the elevator leading to the grinder.

GRINDING AND PRESSING

Fruit grinders and hydraulic presses are available in a wide variety of sizes, ranging from 5 or 6 to 60 or more bushels per pressing. The grinders may be the more commonly used grater type or the hammer-mill type. The latter grinds finer and gives a somewhat higher yield of juice, but it requires more power for operation than the grater.

The pulped apple is usually prepared for pressing by building up several layers of ground fruit with each layer imbedded in a special press cloth and with wooden racks separating adjacent layers. Such a wrapped layer is called a "cheese." The press cloths have dimensions approximately one and one-half times the dimensions of the racks with which they are to be used.

In loading, one press rack is laid on the pressing platform, a form or bottomless box placed on the rack, and then a press cloth is laid over the form and press rack, with the corners of the cloth opposite the sides of the form rack. The apple pulp is allowed to fill the form a little more than level full. The operator should make certain that the corners are well filled and that the top layer is level; otherwise, a cheese may slip out of place. The cloth is then folded over the pulp and the form removed. This forms the lowest of several layers or cheeses. Another rack is laid on top of the enclosed cheese, the form and another press cloth are placed in proper positions and filled with a second lot of pulp. These operations are repeated until the full number of cheeses are completed. Finally, a press rack is placed on top of the last or top cheese, to complete preparations for the pressing operation.

If the apples are over-ripe, the cheese layers should be thinner than suggested in the preceding paragraph. Arengo-Jones (2) suggests that the addition of about 3 percent by weight of a coarse filter-aid, such as Celite 503, to the apples before milling will assist greatly in pressing slippery pulp.

During the pressing operation, the pressure should be built up gradually until a final pressure of not less than 150 pounds per square inch is applied for several minutes. The gage pressure reading is for the ram. Thus, the pressure applied per square inch of pomace must be calculated by dividing the total pressure on the ram area by the area of the cheese. For example, a gage or ram pressure of 150 tons will provide approximately 150 pounds of pressure per square inch on a cheese area of approximately 45 x 45 inches.

The juice yield may be increased by as much as 10 percent in some cases by subjecting the pomace to a second pressing. In such case, the first pressing pomace must be run through a special pomace picker before the second pressing is attempted.

Dry press cloths should be soaked overnight in clear, cold water before using. Press cloths must be clean to permit a free flow of juice Some packers wash them daily in cold water with a washing machine. At frequent intervals, they should be boiled and then rinsed

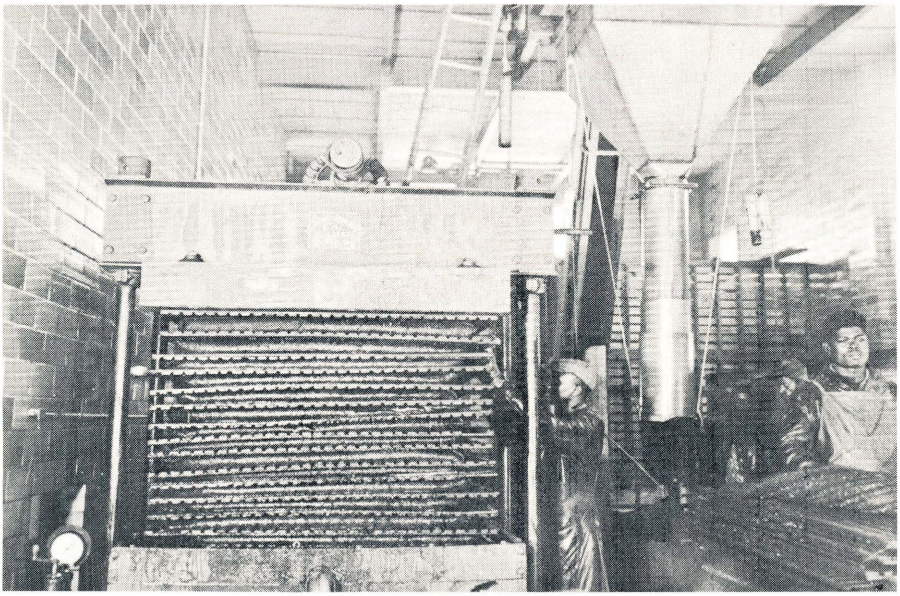

Fig. 8. Grinding and pressing should be done in a room or rooms designed only for these operations. In this plant, the hammer mill is located on the second floor, above the stainless steel hopper and its telescoping tube.

in cold water, or they may be washed and then soaked for several hours in a weak chlorine solution to kill accumulated micro-organisms.

Press racks should be cleaned thoroughly and steamed daily. They should be at least partially dried before stacking. If they are stacked while wet, there is danger of fermentation and of "souring." The stationary mill and press should be cleaned thoroughly by directing streams of hot water at all parts of the equipment after the completion of operations for the day. Clean equipment reduces the danger of contamination by micro-organisms and inspires confidence in consumers who may visit the plant.

The usual yields of apple juice where power equipment is used efficiently range from 150 to 160 gallons of juice per ton of apples. Apples that have been held in well-managed cold storages should provide similar yields throughout the winter months, but those held in warehouses or common storages for several months may give lower yields.

UTILIZATION OF POMACE

A ton of apples yields some 700 to 800 pounds of pomace. Unless some immediate disposition is made of this pomace, it provides a breeding place for vinegar flies, yeasts, and molds. Good plant sanitation implies immediate disposal of the pomace.

Pomace disposal presents somewhat of a problem for small, urban plants. Small plants located on farms may load the pomace on manure spreaders to be hauled to orchards or other fields. No ill effects may be expected from such practices if the pomace is scattered with a manure spreader rather than dumped in piles.

Apple pomace has stock feed value equal to that of corn silage and some plants encourage farmers to haul the pomace away from the plants daily for such purposes.

The larger apple juice plants should have facilities for drying the pomace. Drying is usually accomplished in rotary dryers equipped with steam pipes or coils. The dried product is usually sold to manufacturers of pectin. Pomace that is to be dried for pectin manufacture should be moved promptly from the pressing room to the dryer because of the probability of rapid decrease in pectin content of wet pomace. Apple pomace that is allowed to stand overnight before drying may lose as much as 50 percent of its pectin value. Since dried pomace is usually purchased on the basis of pectin content, prompt delivery to the dryer is essential.

GENERAL EQUIPMENT

The acids in apple juice react strongly with iron, copper, zinc, and lead, resulting in corrosion or erosion. There is a slight reaction of these acids with aluminum and tin. From the standpoints of life of the equipment, the development of off-flavors in the juice, and the possible health hazards, the use of the above-mentioned metals should be reduced to a minimum in juice handling equipment, especially if the juice is likely to be exposed to the metals for any appreciable length of time.

The most satisfactory materials to use are stainless steel, glass enamel, monel metal, block tin, and silver. Tanks may be stainless steel or glass lined. Rigid pipes should be sanitary stainless steel, semi-rigid pipes may be of block tin, and flexible tubing should be steam hose.

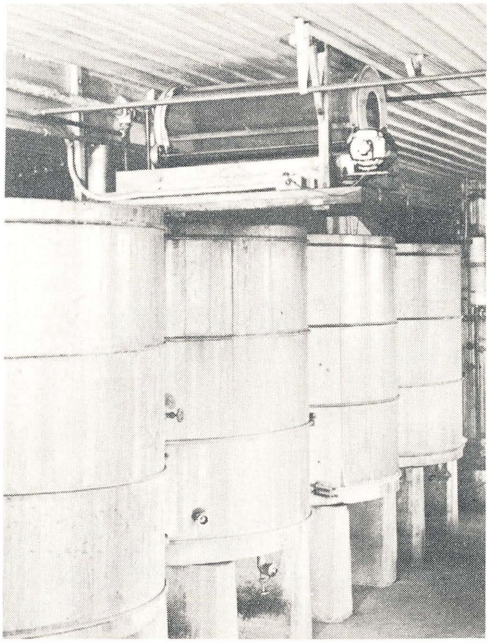

Fig. 9. As this fruit juice screen (top of this picture) revolves, juice passes through it and flows by gravity into any one of four clarifying tanks. The pomace forms into little balls that roll to the outlet end of the screen. Vibrating screens may be used for the same purpose.

Pumps should be non-corrosive and non-erosive in the presence of apple juice, should be non-agitating, and should permit variable capacities as well as variable pressures. Both speed and pressure of pump may be controlled by a by-pass or a variable speed drive.

Wood tanks are often used in juice plants. They present somewhat of a problem to keep them strictly sanitary and to get them in condition for use at the beginning of each season. The hoops must be tightened and they must be kept filled with water for several days before the beginning of each season to swell the staves to prevent leakage. Then during the season of operation they must be scrubbed thoroughly with a stiff brush and hot water at frequent intervals. After the scrubbing, the tank should be steamed thoroughly or filled with a solution of sodium hypochlorite (H.T.H., B.K., Steri-chlor, etc.) containing 300 to 400 parts per million of available chlorine and allowed to stand overnight. Thorough rinsing should follow either treatment.

It is not difficult to keep an apple juice plant in a strictly sanitary condition. Orderliness in arrangement of equipment and general good housekeeping will aid materially in cleaning both the plant and the equipment at the end of the operation for any day. Fortunately, apple juice is easily cleaned from metallic equipment by hot water Pumping hot water through lines and equipment and directing streams of hot water at all external surfaces, followed by a live steam treatment is usually sufficient to clean the usual equipment.

STRAINING THE JUICE

Regardless of the subsequent treatment to which the apple juice is subjected, it should be strained immediately after it is expressed to remove particles of pulp or pomace that have passed through the press cloths. This may be accomplished in small operations by passing it through a double thickness of cheese cloth covering the top of a tank or barrel.

The larger plants are usually equipped with a rotating screen strainer, designed for 8 to 10 revolutions per minute, or with a shaker or vibrating screen. The unstrained juice is fed into the higher end of the screen, and the juice passes through the screen while the pomace is moved to the lower, outlet end where it discharges into a pomace box or tank. The screen should be of stainless steel or monel metal of 150 to 200 mesh.

CLARIFIED OR NON-CLARIFIED JUICE

Even though the apple juice has been strained, it is viscous and cloudy. The former is chiefly due to the pectic material, and the juice is cloudy because of the presence of coagulable solids. When the cloudy juice is subjected to flash-pasteurization, the heat-coagulable substances form a deposit in the bottoms of containers. Furthermore, a more pronounced cooked taste is likely to develop in cloudy than in clarified and filtered juice.

Apple juice that has been filtered has excellent eye appeal. Since appearance is one of the most important factors in developing consumer demand for a product, it must be given high consideration in the apple juice industry.

Since any clarification treatment removes some food constituents from the juice, it would seem that non-clarified juice would result in higher flavor ratings than clarified juice. However, Marshall and Kremer (17) found that clarified juices were usually given higher flavor ratings than cloudy juice by judging panels. They reasoned that this is because the more pronounced cooked taste of the latter tends to mask or hide the delicate apple flavors. Furthermore, a rather large panel of judges gave the best flavor rating to a juice that was clarified among 47 samples packed in 1941 by 40 plants located in various producing areas of the United States (19). This should not be interpreted as meaning that clarified juice possesses better flavor than cloudy juice, but rather as an indication that clarification does not impair flavor as much as might be expected on the basis of theoretical consideration.

The writer (11) made an extensive study of the relation of clarifying treatments to consumer demand and found that 86 percent of

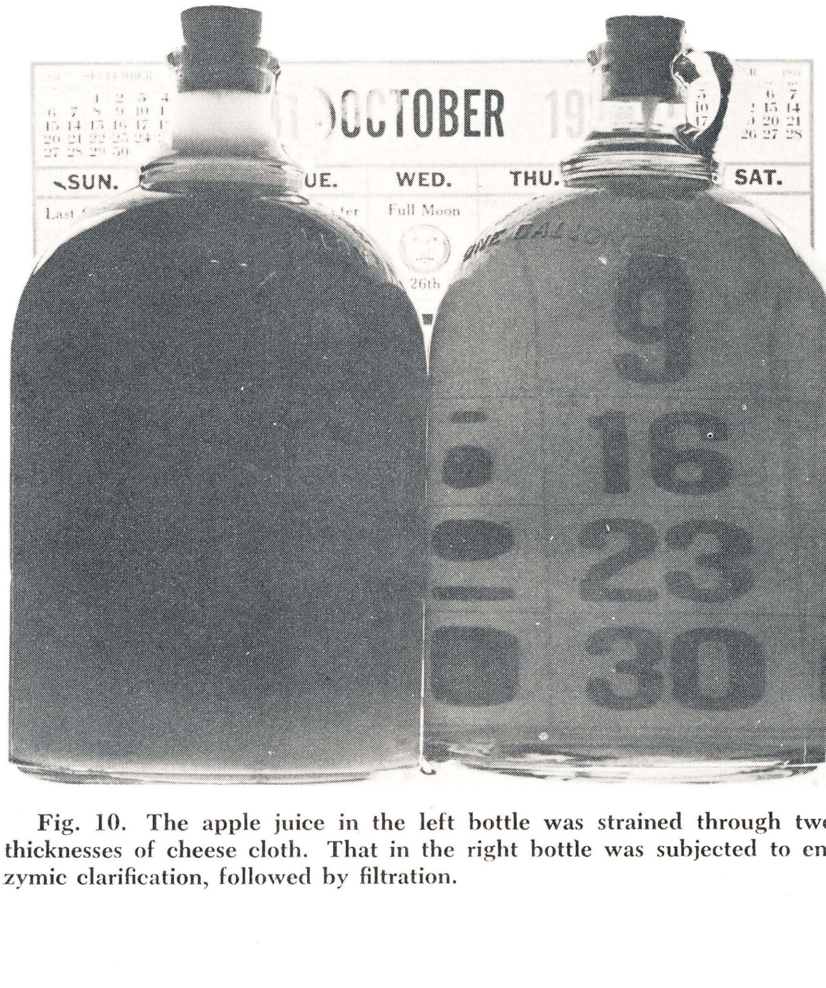

Fig. 10. The apple juice in the left bottle was strained through two thicknesses of cheese cloth. That in the right bottle was subjected to enzymic clarification, followed by filtration.

the consumers preferred to purchase clarified juice when the differential in price between it and cloudy juice was only five cents per gallon. Subsequent tests have substantiated these results with processed apple juice in various consuming areas in Michigan. Clague and Fellers (7) report that experience has shown that clear juice is preferred by consumers in Massachusetts.

Both cloudy and clarified juices are packed by apple juice plants in Michigan. Some plants pack both cloudy and clarified juices, the cloudy juice to be marketed in certain areas that seem to prefer it, and the clarified juice for distribution in other areas. The consumer must be the final judge. If he prefers cloudy juice, it is foolish to try to force him to accept the clarified juice. Generally speaking, however the consumers in most areas that have had ample opportunity to purchase both kinds are willing to pay a premium for juice that has both eye appeal and characteristic apple flavor.

CENTRIFUGING APPLE JUICE

A number of commercial plants run the strained juice through a special high-speed centrifuge immediately after pressing and then pasteurize and pack the resulting juice. This method produces a cloudy juice from which the suspended material that is not held in a finely divided, colloidal form is removed. This practice is recommended if a cloudy juice is to be packed. It is the only continuous process method that has been developed for handling processed apple juice and therefore reduces the time interval between pressing and pasteurization to the minimum. It may be regarded as partial clarification. It results in a full-bodied, cloudy juice from which the non-colloidal suspended materials have been removed, and the product is finding favor in a number of markets.

Centrifuges for fruit juices are built on the same general principle as that employed in cream separators. However, the speed of rotation of the centrifuge bowl is far greater than that for the cream separator. These centrifuges are available in sizes that permit the handling of large volumes of juice. Because of their relatively high purchase cost, they can be used economically only in the larger juice plants.

The bowl and covers of the centrifuge should be constructed of stainless steel or other metal that will not erode in the presence of apple juice since plated parts coming in contact with the juices in such units will wear away rapidly.

It is also possible to subject apple juice to filtration following centrifuging. Since the centrifuge has removed the coarser suspended materials, the juice can be filtered without great difficulty. This also permits a continuous, straight-line operation, rather than batch handling.

CLARIFICATION OF APPLE JUICE

A clear juice may be obtained by filtering immediately after pressing, but since much of the material that is responsible for the cloudiness of apple juice is colloidal in nature, fresh juice filters slowly and with difficulty so that this procedure is not practical. Some clarifying treatment that will break down or aggregate the suspended colloidal material is recommended prior to filtration. Several of the more practical methods of clarification are discussed in the following paragraphs.

Gelatin-Tannin Clarification

The gelatin-tannin treatment is one of the older methods of clarification still in use in some apple juice plants. When gelatin is added to apple juice the colloids of the juice are precipitated because the positively charged particles of gelatin neutralize the negatively charged colloids in the apple juice. To obtain best results, gelatin must be added in the exact amounts required to do the work. An excess of gelatin stabilizes the precipitated colloids. Tannin is therefore added to avoid an excess of gelatin.

Since apple juice varies in composition, each batch should be tested to determine the amounts of gelatin and tannin to be added to obtain most satisfactory clarification. Carpenter and Walsh (5) developed suitable tests for gelatin and tannin, and these tests as modified by Walsh (26) are presented in condensed form. Two test solutions should be made as follows: **Solution 1** – Dissolve ⅓ ounce of tannin in 5.95 fluid ounces of 95 percent alcohol. Then add 23.8 fluid ounces of water and mix thoroughly. **Solution 2** – Dissolve ¾ ounce of gelatin in 23.8 fluid ounces of water and add 5.95 fluid ounces of alcohol. Heat a portion of the water and add the powdered gelatin, slowly, stirring continuously. Then add the balance of the water and dissolve the gelatin by heating and stirring. Add the alcohol and mix well. Keep the solutions in separate stoppered glass bottles. In case the gelatin jells, it can be liquefied when needed by setting the container in hot water.

Four, clear glass quart bottles should be filled to the neck with apple juice and numbered 1, 2, 3, and 4. Ten cubic centimeters of Solution 1 (tannin) are then added to each bottle. Shake the bottle well and then add 5, 10, 15, and 20 cubic centimeters of Solution 2 (gelatin), respectively, to bottles 1, 2, 3, and 4. Shake the bottles and allow them to stand for 10 minutes. The bottle which shows the most clear juice is the one to which the proper proportions of the two materials were added.

To each 100 gallons of juice, 1.25 ounces of tannin, dissolved in two quarts of hot water, should be added in a thin stream while the juice is being stirred. Ten minutes later, the gelatin solution, prepared by dissolving powdered gelatin in hot water, as described in the preceding paragraph, is added in like manner, with constant stirring. The amounts of gelatin to add to each 100 gallons of juice will be 1.5, 3.0, 4.2, or 6.0 ounces, respectively, according to the results of the test with bottles 1, 2, 3, and 4. The juice should be ready to filter after standing 16 to 24 hours.

Gelatin-tannin clarified juice is lighter in color than that subjected to "Pectinol" clarification. Clague and Fellers (7) state that these materials decrease the coloring matter in apple juice 50 percent. Gelatin-tannin clarified juice does not usually filter as readily as that clarified with enzymes. In case too much gelatin has been added, there is a possibility of a precipitate forming after filtration. However, gelatin-tannin clarification produces a very stable juice if proper proportions of each agent are used. The juice usually has better body and viscosity than enzymic clarified juices.

Enzymic Clarification

Several enzymes are known to exert a clarifying action on fruit juices. The one most commonly used for apple juice is sold under the trade name of Pectinol A. It is produced by a mold when grown on the proper nutrient medium. It breaks down colloidal protective materials which are responsible for the cloudy condition of apple juice and causes precipitation and sedimentation of these substances so that filtration is easily accomplished.

The desired quantity of Pectinol A may be measured or weighed out and then added to a one-gallon jug containing some 3½ quarts of warm apple juice. The bottle and its contents are then shaken vigorously at intervals until all the powder is dissolved. The juice containing the Pectinol may then be added to a tank of apple juice while the juice is being thoroughly agitated to provide uniform distribution of the enzyme throughout the batch of juice. The juice is then allowed to stand until sufficient precipitation has taken place to facilitate filtration.

It must be borne in mind that this enzyme has a certain amount of work to do before enough of the colloidal material is broken down in the form of a precipitate to permit filtration at a desirable rate. Since the active agent is an enzyme, the amount of work it can do depends on three factors: (1) the amount of enzyme added per unit volume of juice; (2) the temperature of the juice, and (3) the length of time allowed for the enzyme to work. If any one of these three factors is decreased or shortened, one, or both, of the others must be increased. Obviously, 30 ounces of enzyme-carrying material may be expected to do twice as much work as 15 ounces under otherwise similar conditions. It also follows that an enzyme may be expected to do twice as much work in 20 hours as in 10 hours. Furthermore, enzymes are more active at high temperatures (within the limits encountered in processing plants) than at low temperatures. If 15 ounces give satisfactory clarification in 12 hours at 60° F., some 25 to 30 ounces would be required to do the same work at 40° F. in 12 hours, or the length of time would have to be increased to some 20 to 24 hours.

Complaints have been received from plant operators in late November or in December to the effect that the apple juice was filtering with much greater difficulty than earlier in the season. In most cases, the difficulty was traceable to incomplete clarification prior to filtration. The incomplete clarification was in turn due to the fact that the temperatures of the apples and the processing room were substantially lower than a few weeks earlier. The operator can correct such trouble by lengthening the time for clarification, by increasing the amount of enzyme added, or by raising the temperature of the juice after it leaves the press. The last is usually the most practical and may be accomplished by running the juice through a heat exchanger, constructed by immersing coils of tubing in a hot water bath, to raise its temperature to 60 to 70° F.

Juice made from firm, ripe apples, having a temperature ranging from 60 to 65° F., should filter with a minimum of difficulty after 12 to 15 hours standing with 12 to 14 ounces of Pectinol A to each 100 gallons of juice. Apples that are over-ripe will require a larger quantity of the enzyme. If the juice must be clarified in, say 4 hours, about

3 times as much enzyme must be added to the juice. Experience must be relied upon to determine the exact amounts to use under varying conditions, but the foregoing discussion may serve as an aid in determining approximate amounts, times and temperatures.

The enzymic method of clarification is the one in greatest use at this time. It is probably the most fool-proof of the several treatments described herein. Apple juice clarified with Pectinol A is usually a clear, reddish brown following filtration. While there is actually some loss of coloring matter, the color of the juice is generally regarded as being very good. There is also good retention of flavor. Clague and Fellers (7) report it to have less body and a lower viscosity than juice clarified by some other methods, but our experience indicates that this is of minor importance. Since Pectinol A is a pectin-reducing substance, there also is some loss of pectin resulting in a slight lowering of specific gravity. Possibly the greatest objection to its use is that it is, like the gelatin-tannin treatment, a batch process, requiring at least three holding tanks for practical commercial operation, each tank holding enough juice for a one-half day operation.

Pectinol A is only one of several enzymic clarifying agents. However, investigations conducted over a 14-year period by this Experiment Station have failed to find another enzyme that is as generally satisfactory as Pectinol A, and this seems to be the conclusion of other investigators.

In some cases, perfect and lasting stability has resulted from the enzymic treatment, but in many batches a cloudy condition may develop after some 2 or 3 months' storage of processed juice at room temperature. This usually is followed by the development of an amorphous, dark brown sediment of unknown origin. This condition and methods of stabilizing enzymic treated juices are discussed in a subsequent section of this bulletin that deals with storage and storage problems.

Flash Heat Clarification

Much of the finely divided material in apple juice may be coagulated by heating the juice rapidly to 180 to 190° F., holding the juice at this temperature for a few seconds and then cooling it rapidly to 80° F. The juice is then ready to be filtered, followed by processing at a temperature about 10° F. lower than the temperature to which the juice was heated for clarification purposes.

In commercial practice, the freshly pressed juice is passed directly to a heat exchanger, or flash pasteurizer, where the juice is flash-heated to not less than 180° F. There should then be a very short holding period at this temperature, followed by cooling in a second section of the heat exchanger to a temperature of approximately 80° F. Hot water or steam is used as the heating medium for the first section of the heat exchanger. Water may be used as the cooling medium for the second section, though it is better economy to use apple juice as it comes from the press for this cooling medium. The final flash-pasteurization temperature prior to packing the juice must be lower than the temperature used to coagulate the colloidal material or there will be further coagulation after final pasteurization, and a cloudy juice will result.

This method of clarification is not used in many apple juice plants. While it may remove less of the components of the juice than other methods, it does not produce a juice that can be filtered at a rate that is regarded as satisfactory in most plants. In other words, it does not result in a thorough clarification and little is accomplished in facilitating the rate of filtration.

Bentonite Clarification

The so-called bentonite treatment for clarifying apple juice was developed by Sipple, McDonell and Lueck (22) and is used in a number of commercial plants in the United States. It is a modification and distinct improvement of the flash-heat treatment.

The juice is conveyed from the press to a double-unit flash heater and cooler. In the first section of the heat exchanger the juice is flash-heated to 180 to 190°F. and then immediately cooled in the second section to approximately 80° F. Again, the fresh juice may be used as the cooling medium in the second unit, thereby raising its temperature substantially and resulting in some saving in fuel required to produce the steam or hot water for heating in the first section.

The juice is conveyed from the cooling unit of the heat exchanger to a tank where a suspension of equal parts of finely divided bentonite and filter-aid is added to the juice while it is being agitated thoroughly by a motor-driven stirring apparatus.

For each 100 gallons of juice, 7 to 8 ounces each of fine mesh bentonite and Hyflo super-cel, or its equivalent, must be worked into a thorough suspension in a small quantity of warm apple juice. This

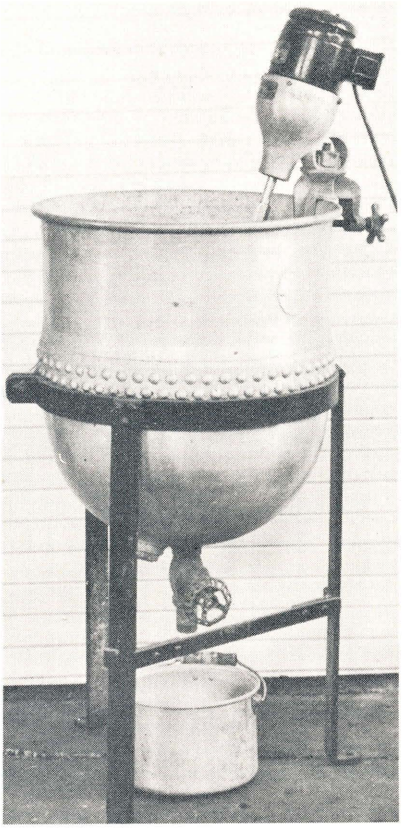

Fig. 11. A kettle and motor-driven mixer used to work bentonite and filter-aid into a proper state of suspension before adding the mixture to the juice in a clarifying tank.

may be accomplished by re-circulating the materials through a small spray pump that will produce a high state of agitation or as illustrated in Fig. 11. Holding the spray nozzle in the pail or vessel containing the materials will produce faster agitation than merely directing the spray at the top of the mixture. After a proper suspension is attained, it is added to the tank of apple juice while the latter is being agitated by a mechanical stirring device. The juice is then allowed to stand one hour or longer, at which time the juice is ready to be filtered.

The heat treatment coagulates much of the colloidal material in the juice, and the bentonite causes this material to flocculate, making it easier to filter the juice. More than the usual amount of filter-aid must be used during the filtration process. Even then some operators experience considerable difficulty in obtaining a satisfactory rate of flow through the filter without rather frequent disassembling and rebuilding of the filter cakes.

The resulting juice is usually a clear, straw color, being somewhat lighter in color than that obtained following enzymic clarification. The juice possesses excellent storage properties, since it is stable and does not result in subsequent sedimentation when held at warehouse and room temperatures.

Mottern and his associates (18) reported off-flavor, failure to obtain a satisfactory degree of clarity, and difficulty in filtering in their investigations with this treatment. However, they state that the bentonite may have been of inferior quality. Our experience and observations have indicated that juice possessing both satisfactory flavor and clarity results when this treatment is employed, but we have experienced much difficulty in filtering some lots of juice subjected to the treatment. On the other hand, commercial packers do not seem to experience appreciable difficulty with filtration. It is probably a case of building up a backlog of experience and "know how" in management of the process.

Tanks for Clarification Treatments

The better methods described for clarification of apple juice are essentially batch methods in that the juice is usually allowed to stand unmolested for one to 15 or more hours before it is ready to filter. Tanks are thus required for these holding periods. Stainless steel tanks are best for this purpose because they may be kept in a strictly sanitary condition with a minimum of effort. Where wood tanks must be used, they must be thoroughly scrubbed with a stiff brush at frequent intervals and then be steamed or be allowed to stand for a time filled with a hypochlorite solution or other sanitizer to prevent the accumulation of a high population of micro-organisms.

Since more or less of the flocculated or precipitated material in apple juice settles to the bottom of these tanks during the holding period following the clarification treatment, filtration may be made much easier and continued for a longer period of continuous operation if only the clearer juice is delivered to the filter during the major portion of this operation, reserving the juice containing much of the sludge for the last portion of the filtration. This is best accomplished

Fig. 12. Stainless steel tanks in a plant that uses the bentonite method for clarification. The two 500-gallon tanks on the right serve as storage tanks for juice that has been flash-heated and cooled in the two heat exchangers shown at the extreme right. The bentonite and filter-aid mixture and finally the filter-aid is added to the juice after it is delivered to the tanks shown with the motor-driven mixers. The small tank at the extreme right is used for pre-coating the filter.

by having two outlets for the juice, one located some 4 to 6 inches above the bottom of the tank to deliver the clearer portion of the juice to the filter, and the other at or in the bottom of the tank to deliver the juice containing most of the sludge to the filter at the end of the run. The latter also serves as a drain when the tank is being washed and cleaned.

Many juice plants find it advantageous to have these clarifying tanks located at levels higher than the floor on which the filter is located. This permits gravity flow of juice to the smaller tank used for mixing filter-aid with the juice before filtration. In most cases the supports for the clarifying tanks are 5 to 6 feet high.

FILTRATION

A number of different types of filters are available. In general, those designed to use a filter-aid are best for apple juice. They should be capable of delivering a clear filtrate at a rate consistent with other operations in the plant when operated at moderate pressures. There should be no iron parts to come in contact with the juice. The portions of the pump that are in contact with the juice should be of stainless steel, bronze, brass, or coated with tin. The filter unit should be constructed of stainless steel, should be glass lined, or should be lined with some material that will not permit direct contact of the juice with iron.

Since most filters are designed for many industrial uses and since apple juice filters at a much slower rate than most industrial liquids, one should take special precaution when purchasing a filter to make certain that it will actually deliver the juice at the desired rate of filtration. In other words, the representative should be requested to supply information on actual delivery rates for apple juice at moderate working pressures rather than for miscellaneous liquids.

The filter-aid or filtering medium most commonly used is a diatomaceous earth or a silicaceous powder. This material is thoroughly mixed with the juice in a mixing tank and is then pumped to the filter unit where the filter-aid, together with the material that is filtered out of the juice, is deposited on a canvas filter cloth or wire cloth surface through which the clear juice or filtrate is passed. These filters are

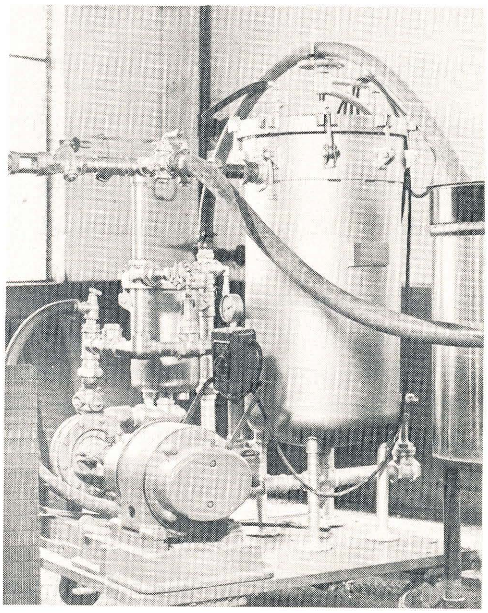

Fig. 13. A filter with vertical baffle plates. A portion of one plate is shown at the lower left. Special canvas or nylon envelopes are used to incase these baffle plates and support the filter cake.

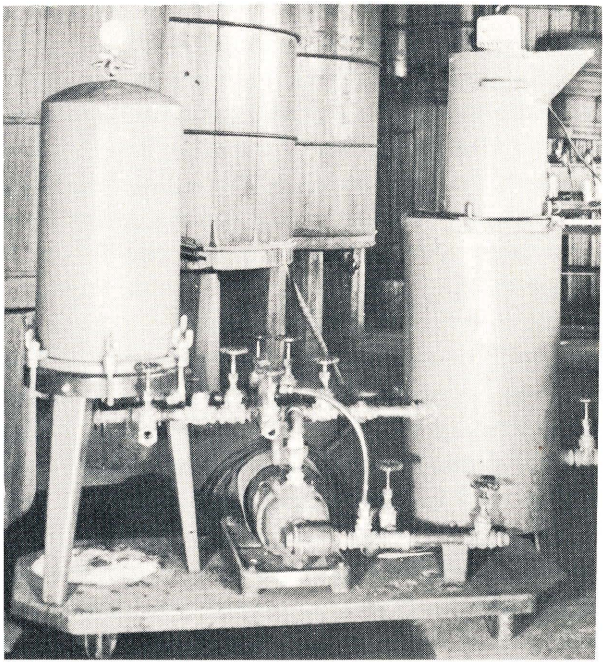

Fig. 14. A fruit juice filter with horizontal plates. The filter unit is at the left and a pre-coating and mixing tank, with a filter-aid feed, is shown at the right of the pump.

equipped with a number or series of plates and frames in the case of filter presses, or several plates or supports for filter cakes in the case of other types of filters. The frames or supports for the filter cloths and cakes may be vertical or horizontal. Either are satisfactory, provided the pressure does not become erratic and provided care is exercised in building up the filter cake. Fluctuating pressures may allow a soggy type of filter cake to slough away at some places on the vertical plates and necessitate stopping the operation to disassemble the filter unit, clean it, and then build up new filter cakes.

The filtering operation is essentially as follows: The plates and cloths are placed in position and the filter is tightened sufficiently to prevent escape of air or liquid from any part except special air vents. Some 10 to 25 gallons of juice, the exact amount depending upon the size of the filter, is placed in a stainless steel or glass-lined mixing tank equipped with a power-operated agitator or stirrer. The agitator is then started, filter-aid is added to the juice at a rate of about 2 pounds for each 10 square feet of filtering surface. After the filter-aid is thoroughly mixed with the juice, the constantly stirred juice is circulated through the filter and back into the mixing tank under low pump pressure. This part of the operation forms a pre-coat on the surface of the filter cloths. Pre-coating is continued until the juice leaving the filter is perfectly clear. This may be determined by filling a tall glass cylinder with juice and observing whether there is any downward movement of materials in the juice. Air in the juice will rise in the form of tiny bubbles while particles of filter-aid will settle downward.

As soon as the pre-coat has been formed and clear juice is being delivered from the filter, the delivery line to the tank that is to contain the filtered juice is opened slowly, so as to prevent a rupture in the filter cakes caused by a sudden change in pressure. Meanwhile, juice is being transferred from one of the clarifying tanks to the mixing tank and filter-aid is added to, and mixed with, this juice at the rate of 1 to 2 pounds per 100 gallons.

Pump pressure is usually regulated by a by-pass and valve on the outlet side of the pump. Low pump pressures should be maintained during the early part of the filtering operation to prevent the formation of a compacted or dense filter cake with a consequent slow rate of filtration. When the rate of flow from the filter begins to decline after continued operation for some time, the pump pressure may be gradually raised to increase the rate of flow through the filter. Eventually, the rate of flow at maximum pressure for the particular type of filter declines to the point when it is no longer practical to continue operation The filter is then stopped, drained, disassembled, cleaned, reassembled with clean filter cloths, and the pre-coating reinstituted.

Filter-aid is available in several grades. The coarser grades may be used when a high degree of clarity is not demanded and the finer grades for high clarity. Obviously, the rate of flow of juice is inversely proportional to the grade of filter-aid used. In general, a grade comparable to "Hyflo Super-cel" or "Speed Plus" is regarded as best for juice made from firm, ripe apples that has been strained and subjected to one of the clarifying treatments described previously.

Considerable skill on the part of the operator is necessary for successful operation of a filter. This skill can be acquired only through experience. It is therefore essential that someone be delegated to handle this operation, and the preceding clarification treatment, that is resourceful enough to acquire this skill without too much difficulty. Even then problems arise that are baffling. Juice made from overmature apples is likely to complicate the problem. In such a case, it may be necessary to alter the clarifying treatment in respect to amounts of clarifying agent used, or time for clarifications, or it may be advisable to increase the amounts of filter-aid added, or to use a coarser grade of filter-aid and be satisfied with a juice having somewhat less clarity. Again, it may be advisable to raise the temperature of the juice for both clarification and filtration.

Small Scale Filtration

Hickok and Marshall (10) developed a simple filter which may be assembled at small cost for use on farms where the amount of juice to be filtered at one time does not exceed 40 gallons (Fig. 15). The mixing and supply tank for the juice and filter-aid may be a 50-gallon barrel, located 8 or more feet above the floor that supports the filtering unit so as to provide a gravity or pressure head on the filter unit. An ordinary garden hose delivers the juice from the supply tank to the filter unit. This hose should be equipped with a gate valve and two nipples at its lower or filter unit end.

The filter unit is an unbleached muslin cloth tube one yard in length and about 3 inches in diameter. A tube of large diameter will not support the filter cake satisfactorily. The tube is made by cutting the unbleached muslin to a width of 10 inches, sewing the sides together, and then turning it inside out. One end of the cloth tube is folded back and then tied over one of the nipples at the lower end of the rubber tube. The opposite end, or dead end, is also folded back, carefully gathered, and then tied with a simple miller's knot.

The cloth tube is then laid horizontally on a copper fly screen that, in turn, is supported by a V-shaped trough, having a slight slope so that clear juice will run out one end into a pail or receptacle.

When the mixture of apple juice and filter-aid (1 to 2.5 pounds per 40 gallons) is fed into the closed cloth tube, the pressure swells the tube to its full dimensions. The juice is then forced out rather uniformly over the entire surface of the tube and the filter-aid forms a cake of uniform thickness on the inside. The first two or three pails of delivered juice will contain some filter-aid and should be poured back into the barrel or supply tank. If the apples are in a firm, ripe condition and if the juice has been subjected to a clarification treatment, it should be possible to filter about 40 gallons of juice before the rate of flow becomes so slow that it is advisable to disassemble the

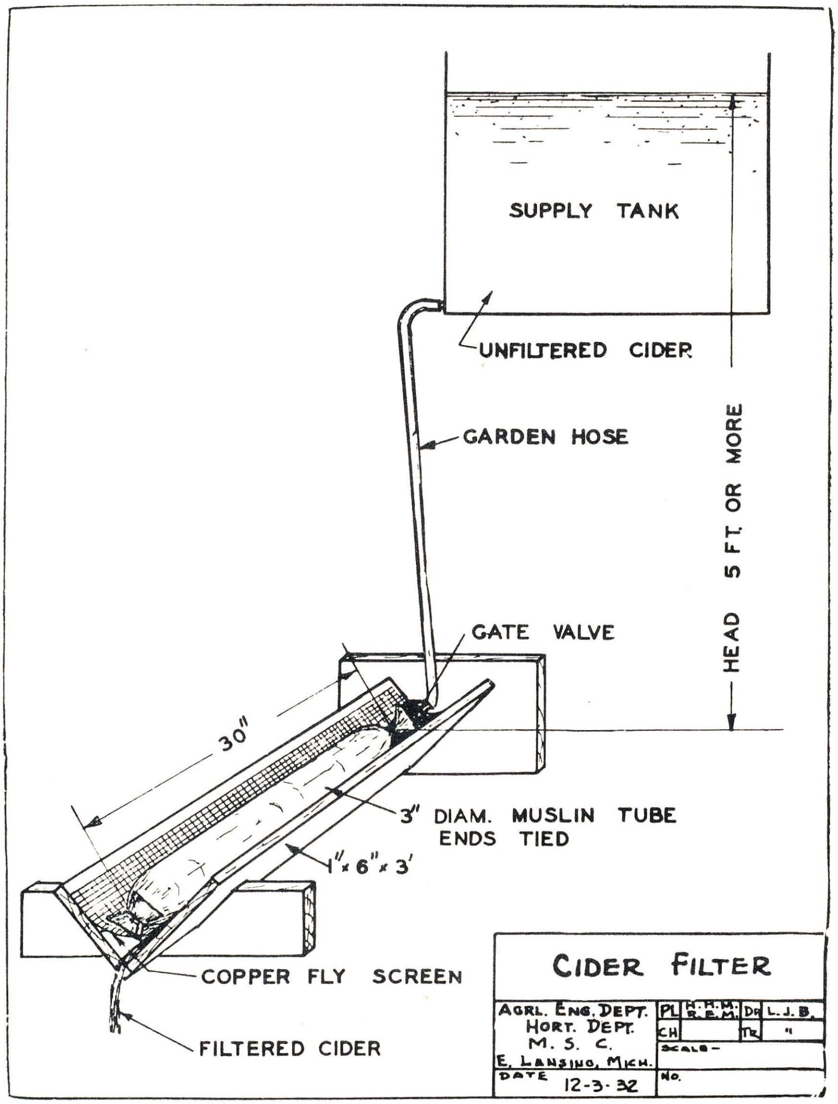

Fig. 15. The essential units of a home-made filter. It may be expected to filter 40 to 50 gallons of apple juice before the rate of flow makes it necessary to disassemble the unit and clean the muslin tube.

unit, clean it in running water and make a fresh start. The rate of flow for a net head of 8 feet was found to be about 1.4 gallons per minute, while increasing the head to 12 feet increased the flow rate to 2.5 gallons per minute.

DEAERATION

Deaeration of certain kinds of fruit juices prior to pasteurization has become more or less standard practice and a few packers of apples have added this practice to their processing lines. Investigations conducted during the past decade, however, do not provide much support for a recommendation that apple juice be deaerated.

Single-stage deaeration was found to be definitely beneficial by Sipple and his associates (22). They found no advantage, however, in providing two-stage deaeration. Mottern, Nold, and Willaman (19) made a survey of apple juice packed in 1940 and concluded that deaeration should be recommended for juice that is to be packed in plain tin cans. Mottern, Neubert, and Eddy (18) state that apple juice does not require deaeration if it is to be packed in glass or in special juice enamel cans. Tressler and Pederson (21, 25) found that deaeration reduced corrosion of cans and that the juice had slightly better flavor than non-deaerated juice. They state that it is advisable to deaerate non-clarified juice to avoid a cooked taste, but conclude that the practice is not of great benefit for clarified juice provided the cans are full.

The Michigan Experiment Station studied the effects of deaeration with a two-stage steam-ejector rather extensively. Most of the tests were made with a pressure of 0.7 inch of mercury (approximately 29 inches of vacuum) though a few tests were made with a single-stage ejector at a vacuum of approximately 26 inches. In most of these tests the temperature of the juice was lowered about 6° F. through the evaporation loss of 3 to 6 percent of the original volume of the juice. Furthermore, there was a very pronounced apple odor in the exhaust steam, indicating that some of the volatile flavoring materials were lost. The two-stage ejector removed approximately 72 percent of the total gases from the juice. It was noted that there was much less foaming when the containers were filled with flash-pasteurized juice that had been deaerated, compared with that for non-deaerated juice.

In general, the deaerated juices were rated slightly better in brilliancy, color and taste after 6 months' storage. However, in some instances the deaerated juice was rather flat in flavor, owing to the loss of flavoring substances. It was concluded that even though the deaerated juice generally rated slightly superior to the non-deaerated juice in appearance and taste, the workers could not recommend the practice in view of the added expense for equipment and operation, and because of the loss of some flavoring materials and some juice through evaporation.

None of the plants located in Michigan at this writing are employing deaeration, but there are some packers in other states who partially deaerate (a vacuum of some 20 to 23 inches of mercury) the juice immediately preceding flash pasteurization, with apparent satisfactory results.

SEDIMENTATION AND STABILIZATION

In 1932, Carpenter and Walsh (5) stated that perfectly sterile apple juice clarified with an enzyme may be expected to deposit a sediment after several weeks' storage. Later, Marshall (12) reported that apple

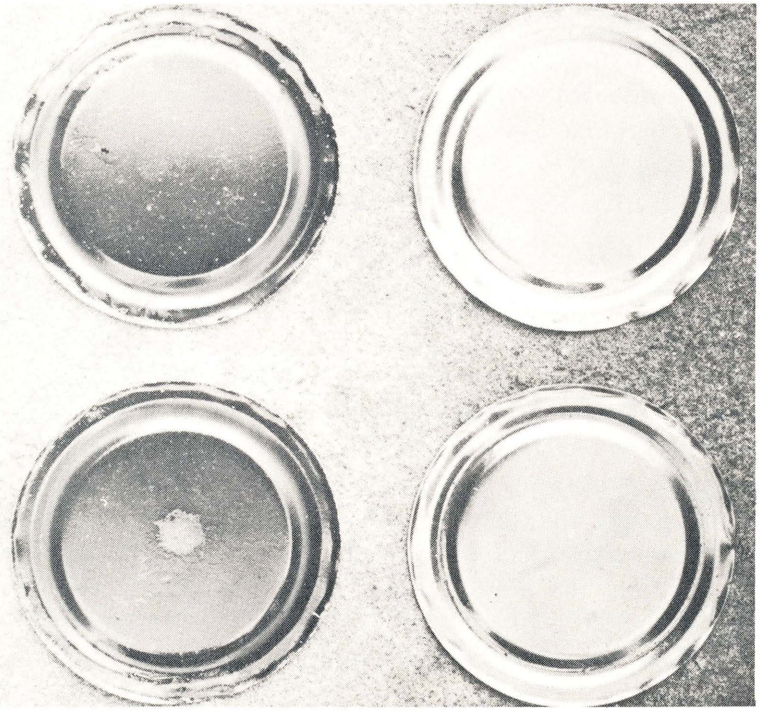

Fig. 16. Bottom ends removed from cans of enzymic clarified apple juice after several months' storage at room temperature. The juice from which the right covers were removed had been fortified with pectin, while those on the left were removed from cans of juice receiving no pectin. The additional pectin stabilized the juice and prevented sedimentation during storage.

juice subjected to enzymic clarification followed by germ-proof filtration deposited a dark brown sediment after 3 to 5 weeks' storage at 70° F., while juice clarified with gelatin and tannin and non-clarified juice remained clear after germ-proof filtration. Deaeration does prevent this sedimentation, according to Pederson and Tressler (21) who also found that the amount of sedimentation varied with viscosity of the juice. Mottern, Neubert, and Eddy (18) concluded that this precipitation, which usually developed within 6 weeks after packing, is not due to further enzymic action, and they suggested that it might be prevented by the addition of 0.1- to 1.0-percent apple pectin.

After a study of 185 lots of apple juice, Neubert and Veldhuis (20) concluded that juices clarified by the enzymic method generally deposited more sediment, and in a shorter time, than juices clarified by other methods and that sedimentation is not associated with variety, maturity of apples, nor methods of handling the juice. An analysis of the sediment showed it to be an inert substance similar in properties to phlobaphenes. In other words, such sedimentation is a colloidal phenomenon.

Investigations made by the writer (14, 15) during a five-year period have shown that apple juice clarified with the Pectinol enzyme may be stabilized against visible precipitation of this amorphous material during storage at room temperature by the addition of small amounts of apple pectin prior to flash pasteurization. Recent studies indicate that 5 to 10 ounces of non-acidulated, starch-free, liquid, apple pectin of approximately 50 grade, added to each 100 gallons of apple juice, may be expected to produce practical results. If, however, the liquid pectin of the same grade is non-starch free and acidulated, approximately two times as much is necessary to accomplish the same results.

This liquid pectin may be added directly to the tank supplying the flash pasteurizer or it may be diluted with apple juice and a measured amount added to each container just before filling. Since the supply tank for the flash pasteurizer is often continuously supplied with juice, a siphon dropper may be installed above the supply tank that will provide a constant supply of pectin at the approximate recommended rate of one ounce to each 10 to 20 gallons of juice.

None of the investigations indicate that this precipitate has any appreciable effect in lowering the quality of the juice. However, it is unattractive and might be expected to create some sales resistance if visible to the consumer. When the juice is packed in tin or in brown glass containers, the precipitate is not visible. It is therefore questionable if the packer using such containers should take any steps to prevent the formation of the sediment.

PRESERVATION

No matter what method of clarification and filtration (except germ-proof filtration) is used in preparing the apple juice, the juice is not sterile and will ferment readily if allowed to remain at room temperature. Even in cold storage at 32° F. it will undergo some fermentation within a week or 10 days. For this reason, it is necessary to kill or inactivate the micro-organisms such as yeasts, molds and bacteria.

There are two general methods of preserving apple juice—physical and chemical. Physical methods include such procedures as pasteurization, filtering through germ-proof filters, freezing, and holding under high atmospheric pressures. The most common chemicals used for preservation of apple juice are sodium benzoate, benzoic acid, potassium metabisulfite, sodium bisulfite, calcium bisulfite, sulfurous acid, and carbon dioxide.

Holding Pasteurization

Pasteurization is the method most commonly used for the preservation of fruit juices in general. It may be classified into what are generally termed "holding pasteurization" and "flash pasteurization." Holding pasteurization consists in raising the temperature of the juice to a recommended temperature level and then maintaining that temperature for a period of 20 to 30 minutes, while flash pasteurization is generally defined as raising the temperature to a desired point in a matter of seconds and maintaining this pasteurizing temperature for only a few seconds. In other words, the juice is simply flash-heated. Holding pasteurization is usually accomplished after the juice has been bottled or canned, while flash pasteurization is done prior to the bottling or canning.

Holding pasteurization has not been used in the better commercial plants since the application of flash pasteurization for apple juice was developed in 1936-37, because it has been impossible to avoid a cooked or pasteurized taste imparted to the delicately flavored apple juice when the method was employed. The only occasion for including

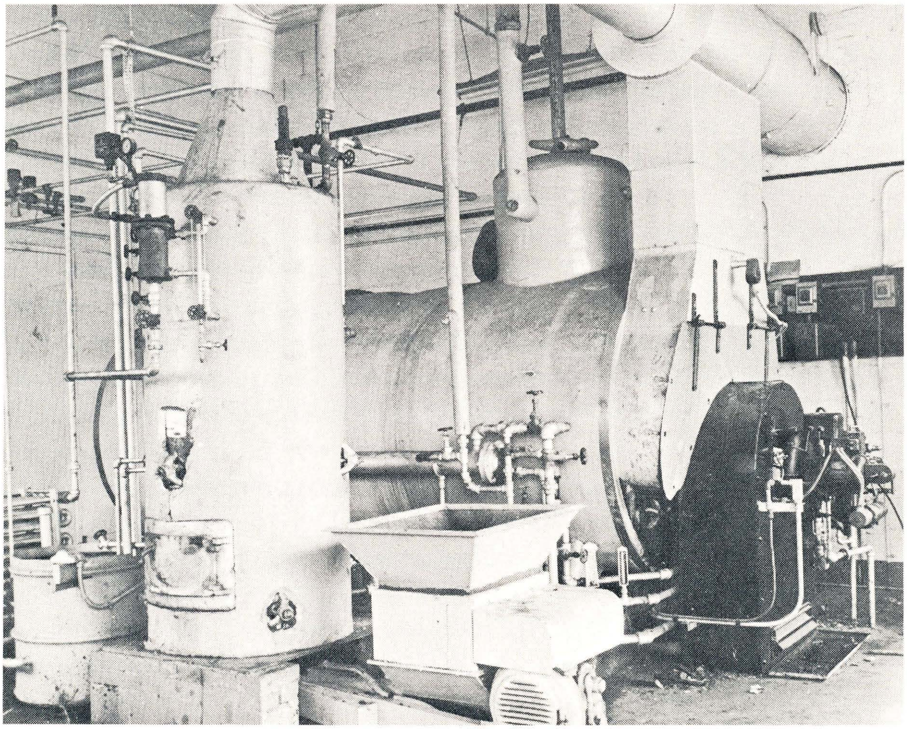

Fig. 17. The 10-horsepower boiler in the foreground is fed by a stoker. It served this operator 3 or 4 years until the increased capacity of the plant made necessary a larger boiler. Then the 50-horsepower, gas-fired boiler in the background was installed.

holding pasteurization in this discussion is to provide the information for the small operator who is not equipped for flash pasteurization and who does not object seriously to the cooked taste.

Yeast spores are killed at a temperature of 150° F. in 10 minutes, and bacteria causing cloudiness in apple juice are killed at a temperature of 158° F. in 30 minutes or a temperature of 176° F. in 15 minutes. A temperature of 175° F. for 20 minutes is necessary to kill the most resistant mold spores. Obviously, the recommendation for holding pasteurization is to raise the temperature of the juice to 175° F. and hold it at that level for not less than 20 minutes. It must be emphasized that the timing must start after the juice in the containers has reached a temperature of 175° F. and not from the time the containers are placed in the heating medium, nor from the time the water bath or medium reaches a temperature of 175° F. Gaging juice temperature by the temperature of the water bath is often disastrous.

For small operations, holding pasteurization is best accomplished by filling the containers and then placing them in a water bath that can be heated to a temperature somewhat above that of the desired pasteurizing temperature. Considerable air space must be left in the bottle to allow for the expansion of the juice when it is heated or considerable breakage will result. One bottle of the lot undergoing pasteurization should be uncapped to permit insertion of a thermometer to ascertain juice temperatures. After the completion of the pasteurization period, the juice should be cooled by placing the containers in a water bath having a temperature of about 125° F. and then gradually lowering the temperature of the bath. Attempts to cool rapidly usually result in breakage of glass containers.

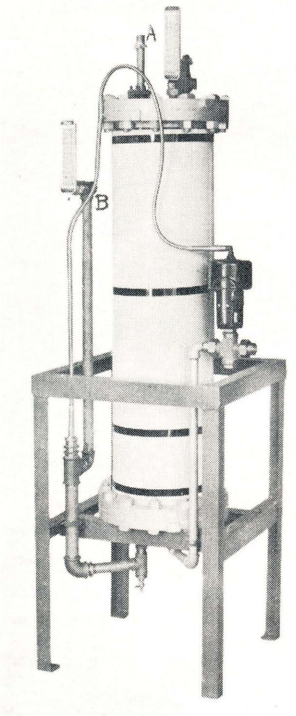

Fig. 18. An insulated heat exchanger with thermostatic control. The casing houses a flattened and coiled stainless steel tube similar to that shown in Fig. 19. Juice enters the exchanger at A and is discharged at B.

Flash Pasteurization

Prior to 1936, tubular heat exchangers, in which the apple juice was heated to approximately 185° F. for 30 to 60 seconds, were used to a limited extent (6, 7). The real development of the processed apple juice industry, however, did not begin until 1937, following the work of Marshall and Kremer (16, 17) in adapting the principle of the flattened tube heat exchanger to the flash pasteurization of apple juice.

The heat exchanger that has been in most general use for flash pasteurization of apple juice consists essentially of a stainless steel or monel metal tube flattened to provide an inside opening of 3/32 to 1/4 inch, formed into a spiral, and the flattened coil housed in a tubular iron pipe or casing. The apple juice flows through the flattened and coiled tube, which is heated by live steam or steam-heated water contained in the larger steam jacket or iron casing (Figs. 18 and 19).

The advantages of this method of flash pasteurization are as follows:

1. The temperature of the juice may be raised to the desired temperature in 3 to 6 seconds in a closed system that prevents contact of the heated juice with air, thus avoiding the prolonged heating with its accompanying development of a pronounced cooked taste.

2. The juice is under a high state of agitation during the heating period, thus assuring uniform heating rather than overheating and scorching of any portion of the juice.

3. The high ratio of coil surface area to cross-sectional area of the juice in the tube and the high state of agitation result in a rapid rate of heat transfer and high heating efficiency.

The capacity of a flattened and coiled tube pasteurizer or heat exchanger is governed largely by the inner cross-sectional area and the length of the flattened tube, the velocity of the juice moving through the tube, and the temperature of the steam or water surrounding the coil. A tube having an original inside diameter of ½ inch flattened to an inside opening of ⅛ inch for a length of 14 feet should be capable of raising the temperature of approximately 80 gallons of apple juice per hour from 60° F. to 180° F. in slightly less than 3 seconds. Such a coil could be installed in a steam jacket made of 4-inch iron pipe 2 feet long.

A flattened and coiled tube flash pasteurizer or heat exchanger designed to raise the temperature of 300 to 350 gallons of apple juice per hour through a temperature range of 120° F., with a total heating time of some 5 to 6 seconds, may be obtained by flattening about 30 lineal feet of 1-inch stainless steel

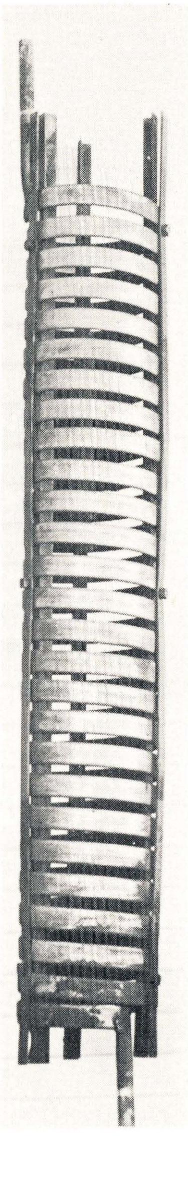

Fig. 19. This 40 feet of one-inch, stainless steel tubing, flattened to one-fourth inch, was removed from a casing similar to that shown in Fig. 18, after 5 year's usage, to permit installation of a larger tube. This one had a capacity of 500 gallons per hour.

tubing to an inside width of ¼ inch, coiling the flattened tube to about 15 turns, 6 inches in diameter and placing the coil in a flanged pipe 8 inches in diameter and approximately 54 inches long.

There are a few units of somewhat greater hourly capacity in Michigan. Increasing the length of the tube just described to 40 feet would increase the capacity about 30 percent. Calculations indicate than an exchanger having an hourly capacity of 600 gallons should have the following specifications: Flatten 38.5 feet of 1½-inch tubing to an inside width of ¼ inch, form it into a coil with a diameter of 8 inches and then install it in a flanged pipe having an inside diameter of 10 inches and a length of 63 to 66 inches.

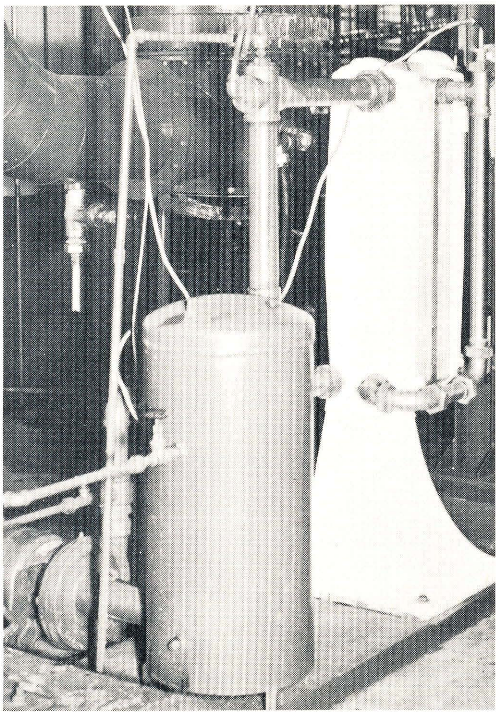

Fig. 20. The white unit is a plate type heat exchanger. It consists of a number of grooved stainless steel plates that insure high turbulence and a consequent high rate of heat exchange. It is easily disassembled permitting easy cleaning. As here illustrated, it also may be used to flash heat and flash cool prior to bentonite clarification.

The foregoing units are custom built. Recently, manufactured heat exchangers that meet the requirements for apple juice (a thin ribbon or sheet of juice moving through the exchanger under a high state of agitation in a few seconds) have been placed on the market (Fig. 20). Where capacities greater than some 300 to 400 gallons per hour are to be expected, these manufactured units should be given consideration.

Heat exchangers should be equipped with an accurate thermometer located in the outlet juice line in a position to permit easy reading. A thermostatic control with the bulb in the outlet juice line should govern the rate of flow of steam into the steam or hot-water jacket. Another method of temperature control is to provide steam at a uniform pressure of 10 to 20 pounds by means of a regulator or pressure reduction valve installed in the line, then set a valve in the outlet juice line to provide the gross or approximate temperature level, and finally provide the fine or accurate temperature control by adjusting the by-pass valve on the pump that supplies juice to the heat exchanger.

While steam is the most practical source of heat for heat exchangers, the medium surrounding the flattened coil or other juice section of the exchanger may be either live steam or water. In case steam is used, it should be made to condense in the chamber so as to take advantage of latent heat of vaporization (when one pound of steam is condensed into water, 970 British thermal units of heat are absorbed by the medium). If water is used as the heating medium in the jacket, the water is heated by means of steam. Some operators claim they are able to maintain a more uniform maximum temperature for the juice by using hot water in the heating jacket. In such a case the water should be maintained at approximately its boiling point.

Tressler and Pederson (25) describe a home-made outfit that may be used for flash pasteurization of small quantities of juice. A 50-gallon barrel, elevated some 8 to 10 feet above the pasteurizer serves to feed the pasteurizer through a garden hose. The lower end of the garden hose is connected with about 70 feet of ½-inch aluminum or copper pipe coiled to fit into a washboiler. The latter is placed over a fire and the water in it heated to 175 to 180° F. A brass faucet at the outlet end serves to regulate the velocity of juice and its temperature.

In operating the flash pasteurizer, it is suggested that water be run through the juice line to obtain an approximate setting for steam pressure and outlet valve, and to clean the system. Then at the end of each operation, the portions of the heat exchanger through which the juice flows should be cleaned thoroughly by running water through it heated to near the boiling point to prevent the formation of a deposit on the inside of the tube. This should include any stop that may be made for the noon recess. At frequent intervals some good cleansing agent like tri-sodium phosphate should be added to hot water that is pumped through the system to remove any deposit that may have accumulated.

Extensive studies at the Michigan Agricultural Experiment Station have indicated that the juice should have a maximum temperature of 170 to 175° F. when it is delivered to the container and that there should be no appreciable drop in temperature from the heat exchanger to the containers under the conditions employed in commercial operations. Temperatures of 180 to 190° F. often impart a cooked taste to the juice. We have found that 160° F. often produces a juice that will keep satisfactorily in tin cans but operation at such temperature does not provide enough leeway for safe operation, especially with juices that are low in acidity.

These findings are in agreement with those of Pederson and Tressler (21, 25) though they state that heating the juice to temperatures above 175° F. imparts some cooked taste. They found no spoilage with a low acid juice from McIntosh apples when it was flash-heated to 163 to 170° F. They state that the better flavored juices resulted from the lower temperatures. It would seem, then, that nothing is to be gained by heating the juice above temperatures that insure good keeping quality and since 170 to 175° F. provides ample leeway in operation, that operators should try to hold the maximum temperature to this range.

Attempts to heat the juice in one unit of a heat exchanger and then cool in a second unit have consistently resulted in failure if the juice was cooled to temperatures as low as 125° F. Experimental results indicate that there is no object in heating the juice in one unit to temperatures substantially above those just recommended and then cooling to a filling temperature of 160 to 170° F. We cannot, therefore, recommend the use of double-unit heat exchangers for apple juice.

Pederson and Tressler (21) have found that flash pasteurization at the temperatures suggested above does not render the apple juice sterile. The yeasts are killed, but some mold spores and some of the more resistant bacteria remain alive in the sealed containers. The juice however, keeps as well as that sterilized by more severe heat treatments. Mold spores are held in check by the absence of air.

When the containers are filled with juice at approximately 170° F., this juice on cooling decreases in volume and a vacuum of some 15 to 20 inches develops, making it unlikely that mold will obtain the necessary oxygen for growth. The surviving bacteria are types that cannot grow in the acid medium provided by apple juice. Thus, it is not technically correct to state that flash-pasteurized apple juice is sterile, yet there should be no growth response from surviving micro-organisms so long as the containers remain hermetically sealed.

Germ-Proof Filtration

From about 1932 to 1935 there was considerable interest in the sterilization of fruit juices by germ-proof filtration or cold sterilization. A few commercial plants were established and several of the agricultural experiment stations, including the Michigan Station, made extensive and thorough studies of this method of processing. While this method of sterilization seems to be used with considerable success in certain European areas, particularly with fermented juices, it is not considered practical for plants packing unfermented apple juice because of the extreme precautions that must be observed in order to seal a sterile product in the containers. For these reasons, the treatment of this subject is limited to a brief presentation.

Clarified and rough-filtered apple juice is passed through specially designed and previously sterilized filter sheets. After the germ-proof filter is assembled and tightened, it must be thoroughly sterilized for 20 minutes by passing live steam through it. The intake and outlets are plugged with sterile cotton to keep the interior sterile until the proper connections are made to filter the apple juice. The apple juice is then pumped through the filter and the special asbestos and wood fiber filter sheets to filter out the micro-organisms. Our investigations show that the juice leaves the filter in a sterile condition if proper precautions have been taken in assembling and sterilizing the filter.

At this point there is real danger of introducing organisms into the sterile juice. Bottles, crowns, and the bottling machine must be thoroughly sterilized with a hypochlorite solution (H.T.H., B.K., Sterichlor, etc.) or some other sterilizing agents, prior to filling the containers. Furthermore, the room in which the bottling is done must be clean and as free from air currents as possible, and the actual bottling should be done under a hood with a current of sterile air flowing into and out of it to keep the contaminated air of the room from coming in contact with the previously sterilized bottles and juice.

While the juice processed by this method has not been heated and is therefore free from any trace of cooked taste, the very fine filtration removes much of the body and color. Furthermore, Marshall (12) found that the juice is rather unstable and is likely to form objectionable precipitates because the enzymes in the juice have not been inactivated. Studies conducted during several seasons with varying procedures to exercise the best possible controls resulted in the development of mold mycelium in 3 percent of all containers packed. For these reasons, this method of processing cannot be recommended for the commercial packing of apple juice.

Carbonation

Since carbon dioxide has an inhibitory action on the growth of molds and since the greatest losses in apple juice processed by germ-proof filtration were due to recontamination of the filtered juice by molds, it would seem that carbonation of the germ-proof filtered juice would solve the problem. Rather good results followed such procedure, but the combined process is rather complicated. The juice must be cooled below 45° F. to permit the absorption of enough carbon dioxide (2 volumes) to inhibit mold growth. This means that a continuous closed system must be provided to convey the juice through the germ-proof filter, through a chilling medium, through a mechanical carbonator, and then through a closing machine designed to fill bottles under pressure. The "bite" imparted by this carbonation has not seemed to appeal to the average consumer. For these reasons, this method was discarded as being too complicated and too impracticable for commercial, large-scale operations.

Brown and Foulk (3) subjected filtered apple juice to storage in a tank under a pressure of 100 to 125 pounds, provided by the introduction of carbon dioxide into the tank of juice, for 3 months. They report that the juice was almost, if not entirely, free from yeasts, had no alcoholic taste, and had a faint carbonation taste when drained from the tank at the end of the storage period. There was what seemed to be a slight cooked taste which was probably a slight storage deterioration flavor. They suggest this method of preservation would be satisfactory if apple juice is to be stored for several weeks or months for local consumption.

Carbonation may be accomplished by adding dry ice at the rate of one gram to each 7 ounces of apple juice before sealing the bottle, to provide approximately two volumes of carbonation. The bottles should be shaken until all the dry ice has dissolved. Breaking of bottles may occur during shaking with possible serious injury to the operator. It is therefore advisable to wrap each bottle in burlap before attempting to shake it.

Freezing Preservation

Apple juice may be held in a frozen condition indefinitely without appreciable change in quality. Freezing stops the activity of the micro-organisms but does not kill all of them. Hence, the juice must be used very soon after defrosting.

Apple juice may be expected to increase about 8 percent in volume when frozen and held at 0° F. Hence, it is essential that sufficient head space be left in the container at time of filling to allow for this expansion on freezing.

Large tin cans used for freezing apple juice should have expansion joints of special construction and barrels should be specially constructed and paraffined. To prevent fermentation of juice placed in large containers before actual freezing takes place, it is advisable to chill or pre-cool the juice by running it through a long coil imbedded in a tank of ice water or brine cooled by mechanical refrigeration. Quick-freezing of apple juice in special containers of consumer size may also be employed. Freezers devised for the citrus juice industry should serve equally well for apple juice.

Freezing of apple juice in consumer-size containers has not been adopted to any appreciable extent at this writing. The probable reason is that the cost of freezing, holding the product in freezer storage, and transportation in refrigerated cars or trucks has been too great for a commodity that can be processed by other means more economically. It is suggested that partial concentration of the juice through freezing to a slushy condition followed by centrifuging to separate the juice from the ice crystals may reduce the cost of containers, freezer holding space, and transportation sufficiently to make handling profitable.

Chemical Preservation

The following suggestions relative to the use of chemical methods for preserving apple juice are condensed from an earlier bulletin of the Michigan Experiment Station by Fabian and Marshall (9), prepared by the senior author:

Benzoate of soda and benzoic acid are not ideal preservatives for apple juice, but they are used extensively with ease and little expense. Unless free from impurities, they impart a "burning" taste which some people find disagreeable. Thus, the U.S.P. rather than the "Technical" grade should be used since the former is free from objectionable odor and taste.

Benzoate of soda is preferable to benzoic acid because the former is more soluble in fruit juices. One pound of the dry powder should be dissolved in one gallon of warm water or apple juice. One pint of this solution will then contain 2 ounces of sodium benzoate.

For strongly acid apple juice that is reasonably free from turbidity and sediment and made from sound stock, from 0.05 to 0.075 percent by weight (7.0 to 11.0 ounces per 100 gallons of juice) is sufficient. Less acid juice made from stock of questionable quality requires 0.075 to 0.1 percent by weight (11.0 to 14.0 ounces per 100 gallons) to preserve it. The amount most generally used is 0.1 percent (14 ounces per 100 gallons of juice). It is necessary to declare both the presence of the sodium benzoate and the amount added in percent by weight on the label of each container of juice offered for sale.

Sulfurous acid, sometimes used as a preservative for fruit juices, is more toxic for mold spores and bacteria than for yeasts. Apple juice made from sound stock and stored at 60° F. in clean containers may be preserved for more than a year by the addition of 0.1-percent sulfurous acid.

Some chemicals which contain sulfur dioxide in available form are potassium metabisulfite, sodium bisulfite, calcium bisulfite, and sulfurous acid. The first named is probably the best. It is used at the rate of 0.2 percent (25 ounces per 100 gallons) to provide the equivalent of 0.1 percent sulfur dioxide. These materials tend to bleach the apple juice and they impart a disagreeable taste when first added and are slightly toxic to human beings. They will not prevent spoilage unless the juice is kept cool. The regulations of some states do not permit their use.

CONTAINERS

Both glass and tin containers of various sizes are used for processed apple juice. Glass containers used for juice that is processed by heat treatment should be capable of withstanding temperature differentials of as much as 60 to 70° F. without cracking, otherwise considerable loss of both containers and juice may result in both filling and cooling

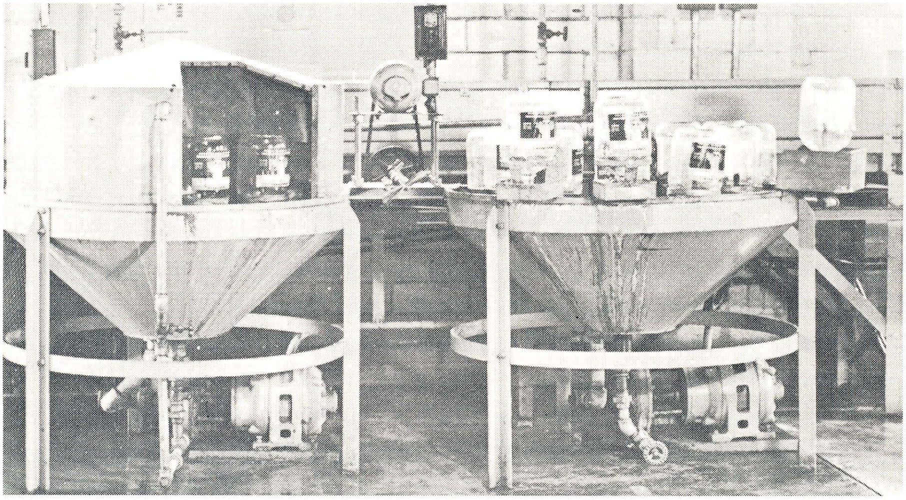

Fig. 21. Equipment for washing one-gallon bottles. A detergent is pumped through jets into the inverted bottles as the latter make the circuit in the hooded washer at the left of the picture. Between the two units is a motor-driven brush. Bottles are rinsed in the right unit then are pre-heated with steam before filling with flash-pasteurized juice.

operations. Clear glass permits consumer inspection of the displayed product and, if the juice has been filtered, provides considerable sales appeal. Most packers of non-clarified apple juice and some producers of filtered juice are using brown bottles at this writing. The brown glass serves to conceal any sedimentation and the unattractive appearance of juice that has not been clarified. Most packers use crowns that are spot-lined for narrow-mouthed bottles to keep the juice from coming in contact with cork. One-gallon bottles should have closures fitted with rubber gaskets rather than cardboard ones to provide a tight seal for bottles having uneven lips.

Tin containers should be lined with a special juice enamel. Apple juice placed in plain tin cans usually develops off-flavors and the color fades, owing to the reaction of the juice with the tin. There is considerably less loss of both juice and containers when tin is used compared with bottles, and the tin containers lend themselves to less careful handling than glass containers. As pointed out later, the cooling equipment may be more compact for tin than that necessary for cooling glass-packed juice. It is likely that substantial quantities of apple juice will be packed in both kinds of containers and that even individual operators will pack in both kinds. Each process possesses certain advantages and certain disadvantages from the standpoints of both processors and consumers.

With the advent of flash pasteurization and the establishment of a processed apple juice industry in Michigan, it was thought that a can holding 20 ounces (303 x 509) would be the ideal consumer size. There was even an attempt to make this the standard-size tin container for Michigan apple juice. There were, however, some packs in No. 10- and 24-ounce cans and in one-gallon glass bottles. For a time most of the processed juice was packed in 20- and 24-ounce tins. Then the 6¾-ounce tin was introduced and finally in 1940 and 1941 some juice was packed in 46-ounce tins.

The tin allocation order in 1942 made tin unavailable for apple juice Some packers had a limited supply of tin on hand, but the bulk of the pack was in glass. Twelve sizes of tin and glass containers were packed in Michigan that year. All packs for 1943 and 1944 were in glass, and the industry had settled on four sizes of containers with the volume distribution as follows: 1943—52 percent in 32-ounce; 24 percent in 16-ounce; 22 percent in one-half-gallon, and 2 percent in one-gallon. 1944—66 percent in 32-ounce; 9 percent in 16-ounce; 23 percent in one-half-gallon, and 2 percent in one-gallon. These data indicate a decided trend towards the larger size containers for glass such as the 32-ounce and one-half-gallon bottles. Just what sizes of tin will be most popular is subject to question, but there undoubtedly will be a heavy pack in 46-ounce and possibly 24-ounce cans. Whether the 6¾-ounce can that was gaining in popularity in some areas of consumption before World War II will again be used for a substantial portion of the pack when tin again becomes available for apple juice is questionable.*

Glass bottles that are to be reused for apple juice must be cleaned thoroughly. They should be soaked in a 3-percent solution of caustic soda at a temperature of 145° F. for five minutes, then brushed, then resoaked in caustic soda solution at a temperature of 140 to 145° F., followed by rinsing in clear water. This treatment should suffice if the containers are to be filled with flash-pasteurized juice. If they are to be filled with cold-processed or germ-proof filtered juice they should be rinsed in a hypochlorite solution just before filling.

*Fifty nine percent of the volume of apple juice packed in Michigan from the 1946 crop of apples was packed in 46-ounce tin containers, and 18 percent in one-half-gallon and 9 percent in 32-ounce glass containers.

Tin cans should pass through a can washer installed in the line that delivers them to the filler to remove dust. This operation is usually accomplished by directing live steam or a hot-water spray into the cans as they pass a designated station in the delivery line (Fig. 27).

FILLING THE CONTAINERS

In plants of small capacity the cans may be filled with flash-pasteurized juice by hand. In such cases, a rubber tube may be used to deliver the juice from the outlet of the heat exchanger to the cans by holding the loose end of the hose so as to fill from the bottom of

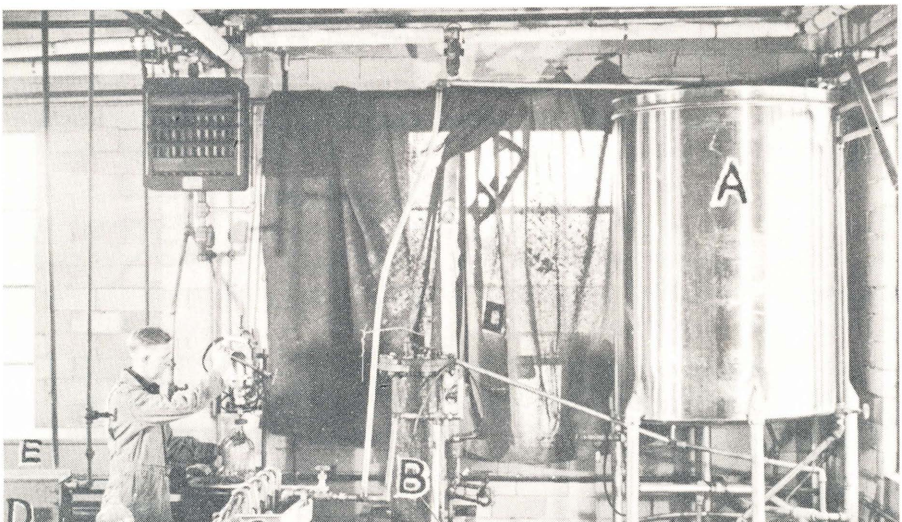

Fig. 22. Filtered juice accumulates in the stainless steel tank A, is pumped through the flash heat exchanger B, and then is delivered to the siphon filler C. The operator is sealing a one-gallon glass container. The bottles are pre-heated with steam in the hood D before filling. The filled and sealed containers are cooled in the spinner cooler E.

the container and thus reduce foaming. The operation may be speeded up by having two leads of rubber hose, a larger one for rapid filling to within about one inch of the top of the container and a hose of small diameter operated by a second individual whose duty is to finish the filling at a rate that will permit full cans without appreciable loss.

It is also practical to fill cans as they are moved forward in single file on a belt by having a stainless steel pipe above the middle of the can line that allows juice to feed into the cans from small holes in the bottom of the pipe line. In such a setup, the belt line carrying the cans should be equipped with a variable speed drive that will permit accurate matching of rate of juice flow with completion of filling as the cans pass the last pipe perforation.

The larger commercial plants should have automatic can-filling equipment (Fig. 27). The supply tank for the filler should have a minimum of surface exposure for the juice because the hot juice may attain somewhat of a cooked taste if held for an appreciable length of time exposed to air.

Glass bottles should pass through several feet of hooded conveyor into which live steam is admitted through a perforated pipe to warm the bottles before filling them with hot juice (Fig. 23). Otherwise breakage is likely to occur even in glass designed to withstand large

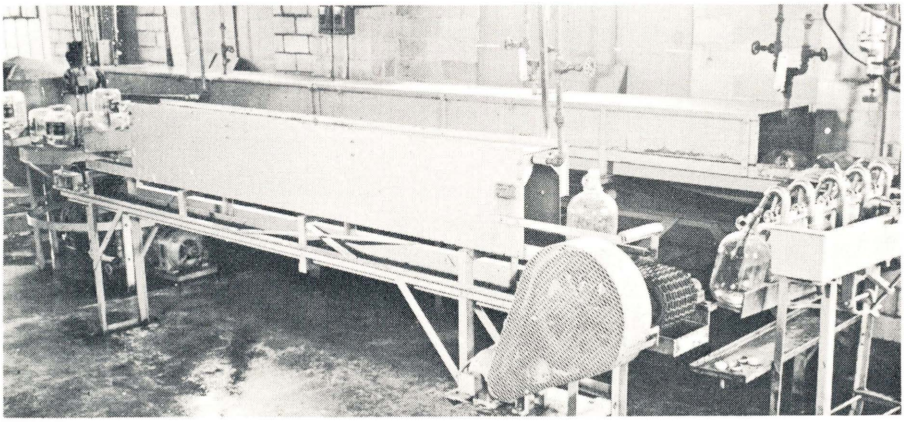

Fig. 23. Same plant as Figs. 21 and 22. Bottles are pre-heated with steam, to prevent breakage during filling, in the hooded conveyor in the foreground. The 35-foot spinner cooler in the background is designed to supply cooling water at 90 to 100° F. for 2 or 3 minutes, and tap water for the balance of the 7-minute cooling time. The progressor for the cooler is an endless chain conveyor with cross bars to hold individual bottles in place. These cross bars have rubber gaskets to prevent the hot glass from touching cold iron.

temperature differentials. Heating the empty glass containers to the point where they may still be handled with the bare hands is common practice. Even the glass of best quality for juices should have a temperature in excess of 100° F. when delivered to the filling station.

Glass bottles are usually filled with siphon fillers in the plants of small to medium size (Figs. 22 and 24). Two to six or eight siphon fillers may be assembled to feed directly from the flash pasteurizer or from a small supply tank. The latter is desirable. These siphon tubes are available in various sizes suitable for filling containers varying in size from 16 ounces to one gallon. They permit making a substantial portion of the fill from near the bottoms or mid-portions of the containers and thus avoiding serious foaming.

Automatic bottle filling equipment should be a part of every plant that packs as much as 50,000 cases of bottled juice during the season. Again, the supply tank should be designed to expose a minimum surface of the hot juice to the air to lessen the tendency to develop a cooked taste.

Head Space in Containers

Containers should be completely filled with juice that has been flash-pasteurized, but enough head space should be left in containers that are to be frozen or subjected to holding pasteurization to allow for expansion caused by subsequent freezing or heating.

When containers filled with juice at 170 to 180° F. are cooled to room and warehouse temperatures, the juice contracts sufficiently to develop some 15 to 20 inches of vacuum. Since flash pasteurization at usual temperatures does not actually kill all of the mold spores, those remaining alive must be kept inactive by an absence of oxygen or air. Slack fills with hot juice permit considerable air to be sealed in the container with the possible subsequent development of mold. Furthermore, slack fills enclose enough air to permit some oxidation of the juice and consequent development of aged or oxidized taste and poor color.

Tests at the Michigan Agricultural Experiment Station have shown repeatedly that the juice in containers having 6 to 7 percent of head space on cooling to room temperature develop off tastes due to oxidation and usually precipitate a greater amount of sediment than that in containers filled to the maximum consistent with practical operation. Furthermore, an occasional container with slack fill has developed mold after several weeks' storage. Properly filled cans of the 20- to

24-ounce sizes should not show more than one-eighth inch of head space after they are cooled to room temperature. This is equivalent to about 2 percent of the volume of the container.

Foaming of apple juice during the filling operation sometimes makes it difficult to obtain a good fill. Deaeration of the juice prior to flash pasteurization removes the air from the juice and prevents foaming. Foaming may also be very substantially reduced by filling from tubes that extend nearly to the bottoms of the containers.

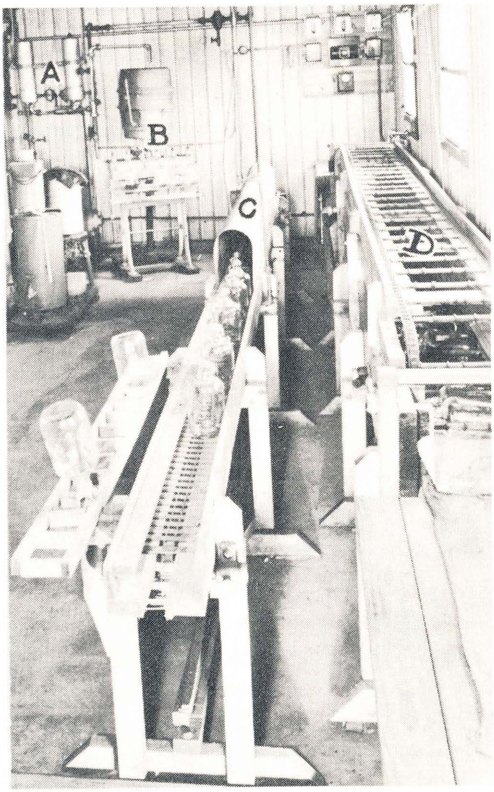

Fig. 24. A view in a juice plant designed to handle the juice stock from an individual fruit farm. Two small heat exchangers for flash pasteurization are shown at A. A small supply tank for pasteurized juice and siphon bottle fillers are shown at B. Clean bottles are pre-heated with steam at C and a spinner cooler with a chain progressor is shown at D. The cooler spins the filled bottles in a bath of water. The cold water intake is at the exit end of the cooler.

HOLDING INTERVAL BETWEEN HEATING AND COOLING

In general, the shorter the time interval between filling and sealing the containers and the subsequent cooling of juice, the better will be the flavor of the juice. Experience at this Station has indicated that juice packed in tin cans may move directly from the closing machine to the can cooler with no ill effects. On the other hand, there have been no measurable ill effects resulting from delays of as much as one minute between the time the can is sealed and the time that cooling begins. Longer periods of delay are usually accompanied by flavor impairment.

Designing the can handling line in such a manner as to cause the cans to be turned to a horizontal position after sealing and then rolling forward for 5 to 15 seconds before reaching the can cooler seems to be both safe procedure and entirely practical.

Glass bottles with narrow mouths must be placed in a horizontal position for about 20 seconds to provide ample opportunity for the hot juice to come in contact with the neck of the bottle and its crown. In every case where we have failed to turn bottles from a vertical position immediately after sealing we have had losses due to the development of mold mycelium. In other words, the hot juice must have an opportunity to fill completely the neck of the bottle to prevent spoilage.

COOLING

Throughout the portions of this bulletin that deal with flash pasteurization, stress has been laid on the necessity of reducing the time during which the juice is held at high temperatures to the minimum. Hence, rapid cooling of the juice to temperature levels that will not result in flavor impairment but at the same time will be high enough, in the case of tin containers, to cause the cans to dry rapidly is desirable. We have found that cooling tin containers rapidly to approximately 100° F. produces the most satisfactory results, while juice packed in glass may be cooled to somewhat lower temperatures.

Cooling is usually accomplished by causing the filled containers to revolve in a horizontal position under sprays of cold water. In a study made to determine the relation of rate of rotation of 303 by 509 cans to rate of cooling of the juice, it was found that the optimum rate of rotation is about 100 revolutions per minute. This speed of

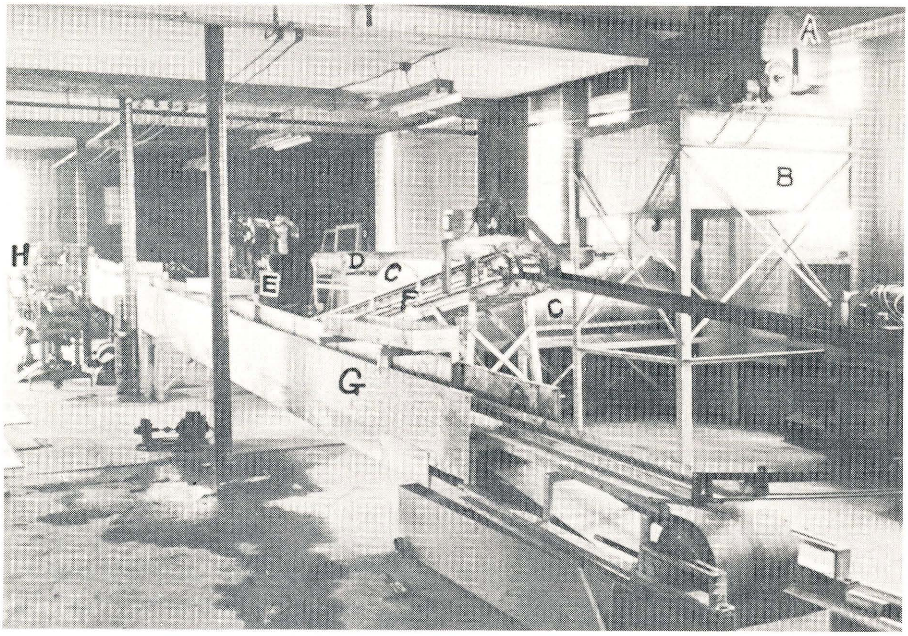

Fig. 25. Handling and processing in a plant that packs cloudy juice. The juice from the press is pumped to the rotating screen A; the strained juice is collected in tank B; the juice flows by gravity into one of the tanks C where it is fortified with ascorbic acid; flash pasteurization is accomplished in the heat exchanger D and then delivered to the can filler (not shown); the cans are sealed at E; the conveyor F is employed to hold the juice at the closing temperature for a short time while being transferred to the spinner cooler G. This photograph was made before the necessary pipe connections had been installed.

rotation permits an air space on the top side of the can which in turn increases the amount of agitation of the juice. Slow rotation of the container does not provide enough agitation of juice to result in a high rate of heat transfer, while very rapid rotation causes the juice to revolve with the container and to develop an air space at the center of the liquid rather than at the top (13).

The essentials of a can cooler are as follows: a rubber endless belt, some 8 to 10 inches in width, moving at a rate that will cause the cans to rotate 100 r.p.m.; adjustable sheet metal sides to keep the cans in line, to confine the water spray, and to permit ready adjustment for use with cans of varying sizes; a belt installed in such a manner as to provide approximately one foot rise in elevation per 15 feet of horizontal distance, so as to balance the rate of forward movement of cans with the rate of feeding from the closing machine; a series of spray nozzles above the rotating cans that will produce fine sprays or an arrangement that permits spinning in a water bath.

Assuming that 300 gallons of juice per hour are to be packed in 46-ounce cans (404 x 700), can closing will be at the approximate rate of 14 cans per minute. If the cans are to be cooled in 2 minutes, the effective length of the can cooler will be 4.25 (diameter of can) times 14 times 2, or approximately 120 inches or 10 feet. If the same volume of juice is to be cooled in 3 minutes, the cooler should be approximately 15 feet long. To make these cans rotate 100 r.p.m., the speed of the belt in feet per minute can be determined by multiplying the circumference of the can in inches by 100 and dividing by 12 inches ($4.25 \times 3.1416 \times 100 \div 12 = 111$ feet per minute). Spray nozzles of a type that produces a fine spray of tap water should be spaced at intervals of one to two feet. Recently, some plants have installed water drip pans over the spinning cans as illustrated in the cover photograph and in Fig. 25.

A still simpler, but less effective, can cooler may be made by having two angle-iron guide rails or runners spaced to accommodate the length of the cans and installed so as to provide a fall of approximately one foot in 15 feet of length, and then installing a water pipe with spray holes or nozzles on the middle of the line. In this case the cans

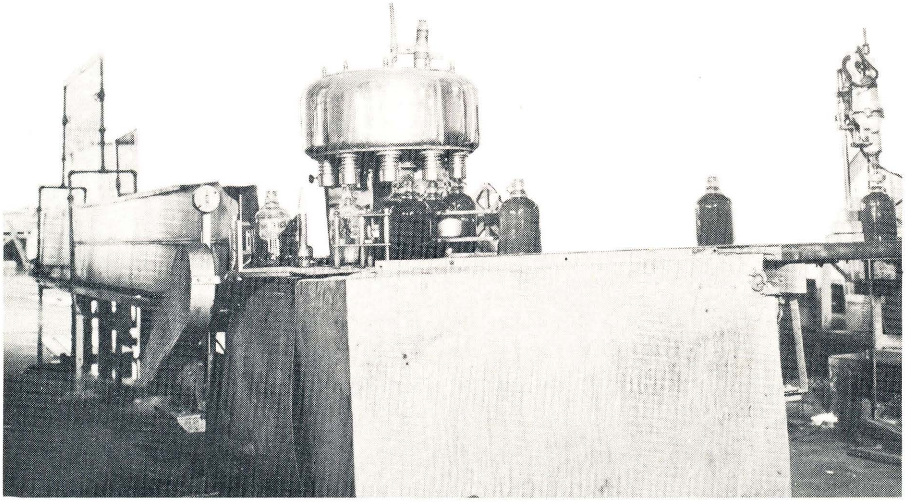

Fig. 26. From left to right: preheater for one-half gallon bottles; rotary bottle filler; motor-driven conveyor for filling bottles, and a motor-driven post drill used for screwing caps on bottles. Note the foot-operated lever at lower right used to lower the drill head and thus provide the necessary friction on the bottle cap.

move forward by gravity. Such an installation does not confine the spray and is therefore rather sloppy.

Glass containers must be cooled slowly, and the initial cooling water must be at a temperature of not less than 90 to 100° F. to prevent breakage (Figs. 23 and 24). One-gallon bottles filled with juice having a temperature of 170 to 175° F. may be cooled, without breakage, in about 7 minutes by spraying the rotating bottles for about 2 minutes with water at a temperature of 90 to 95° F. followed by 5 minutes under tap water sprays. The design of the cooler should be such that cold tap water is not permitted to flow toward the receiving end of the cooler and thus come in contact with hot glass. Such coolers are usually level and are designed to move the bottles forward on a belt that will cause the bottles to rotate about 100 r.p.m. For one-gallon and one-half-gallon bottles, a chain conveyor with rubber covered cross bars elevated about 2½ to 3 inches above the rapidly moving rubber belt may serve to control the rate of forward movement. The cooler must be designed to prevent any possible contact of cool metal with the hot glass of bottles after they are fed onto the cooler.

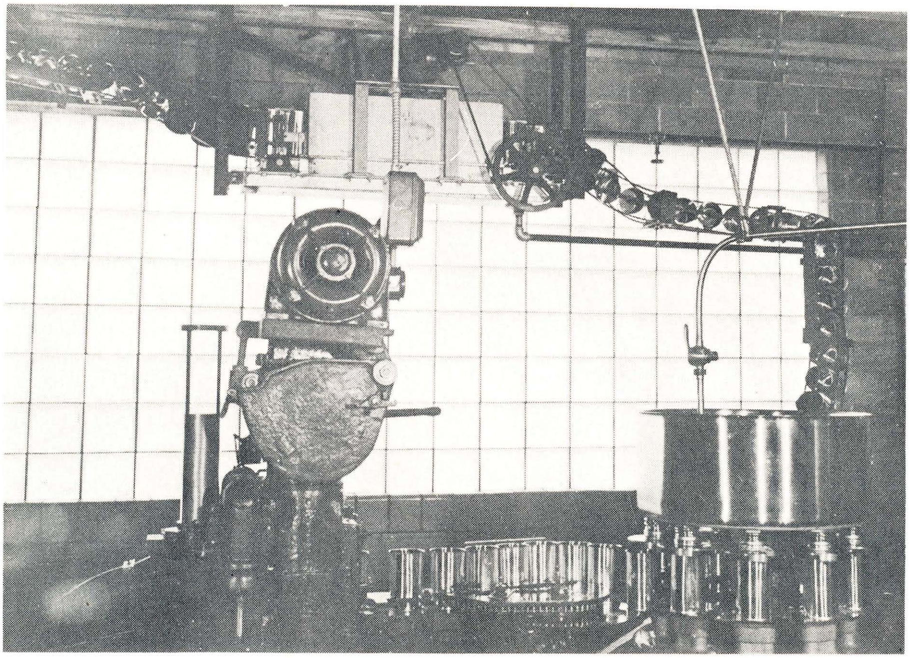

Fig. 27. A can washer (under ceiling), a rotary can filler for 46-ounce cans, and a closing machine in a modern apple juice plant.

Canning factories equipped with a hot-water exhaust tank and metal belt conveyor may use such equipment for cooling glass bottles. The rate of cooling is rather slow with such equipment because the juice cannot be agitated. Cold tap water may be fed into such a tank at the exit end for containers and discharged at the receiving end for containers, thus providing a satisfactory temperature gradient from one end of the tank to the opposite one.

Tin cans must be dried before labeling and packing into cases or cartons to prevent rusting. They will dry in a comparatively short time in still air if the juice temperature approximates 100° F. but not fast enough to permit continuous operations. Stacking to permit drying increases handling costs and is space-consuming. Continuous, straight line cooling of containers may be accomplished in a few minutes by causing the cans to rotate while progressing forward in the presence of air moving at high velocity. It is suggested that cans may be delivered from the cooler onto angle-iron guide rails, which in turn are housed in a sheet metal tube about one foot square. A motor-driven fan installed at the discharge end of the dryer, having a capacity of about 1,000 c.f.m., would drive air at warehouse temperature along the can line in a direction counter to that in which the cans progress by gravity. Since the high rate of evaporation in the presence of high velocity air movement, would dry the cans rapidly, some 10 to 15 feet of dryer should suffice for plants packing 300 to 500 gallons per hour.

PACKAGING AND STORAGE

As soon as the containers are dry they may be labeled and then packaged in cases for storage or shipment, or the individual containers may be stored until just before shipment and then cased at that time. The latter method of handling permits inspection of each container after it has been held in storage and sometimes saves handling expense.

The storage warehouse for processed apple juice should be cool. Any deterioration in quality or tendency to precipitate out a sediment will occur in a much shorter time at room temperature than at temperatures in the vicinity of 50 to 60° F. The ideal storage temperature is just above the freezing point but it is not economical to provide such temperatures specifically for apple juice. In case space in a cold storage located on the premises is available for storage of apple juice, it should be utilized for such. Otherwise a reasonably cool and dry storage should be used.

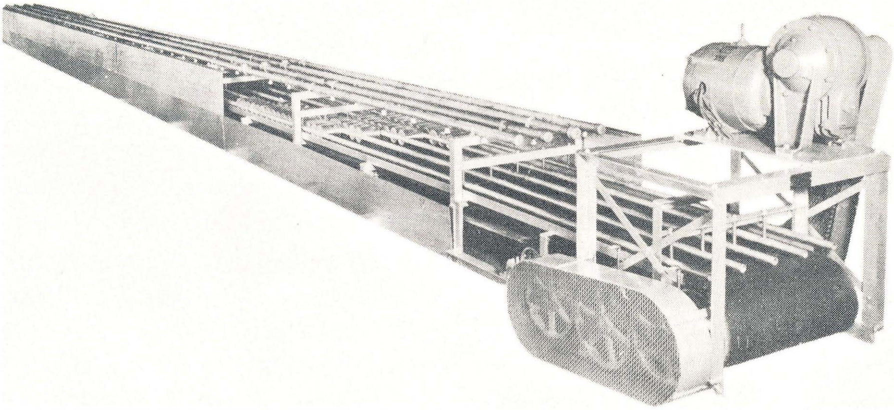

Fig. 28. A four-lane spinner cooler with a portion of one side removed to show belt, guide rails, and spray nozzles. The left or exit end must be elevated enough to prevent cans from discharging until the belt is loaded to near full capacity.

PLANT LAYOUT

Before any attempt is made to design a building for the packing of apple juice, careful estimates of the probable maximum daily and annual capacities and the methods of processing and kinds of equipment to be used should be determined. The building can then be designed to accommodate the equipment required rather than attempting to fit equipment into a predetermined building. Ample space should be allowed for all operations without overcrowding. Most plants soon become too congested. Possible increases in pack volume are too seldom anticipated at the time the original plans are prepared.

The various operations that provision must be made for in a typical commercial plant are: receiving of raw product, storage, grading, washing, grinding and pressing, handling pomace, cleaning press cloths, clarification, filtration, pasteurization, filling and closing containers, cooling filled containers, drying containers, labeling, casing, and storage. In addition, there must be a boiler room, storage space for empty containers and cases, and a locker room with toilet and washing facilities.

The foregoing operations indicate the need of five distinct areas or rooms in addition to the locker room and toilet facilities and any possible provision for drying pomace. The receiving, storage, grading, and washing operations constitute one unit of the plant. The washed

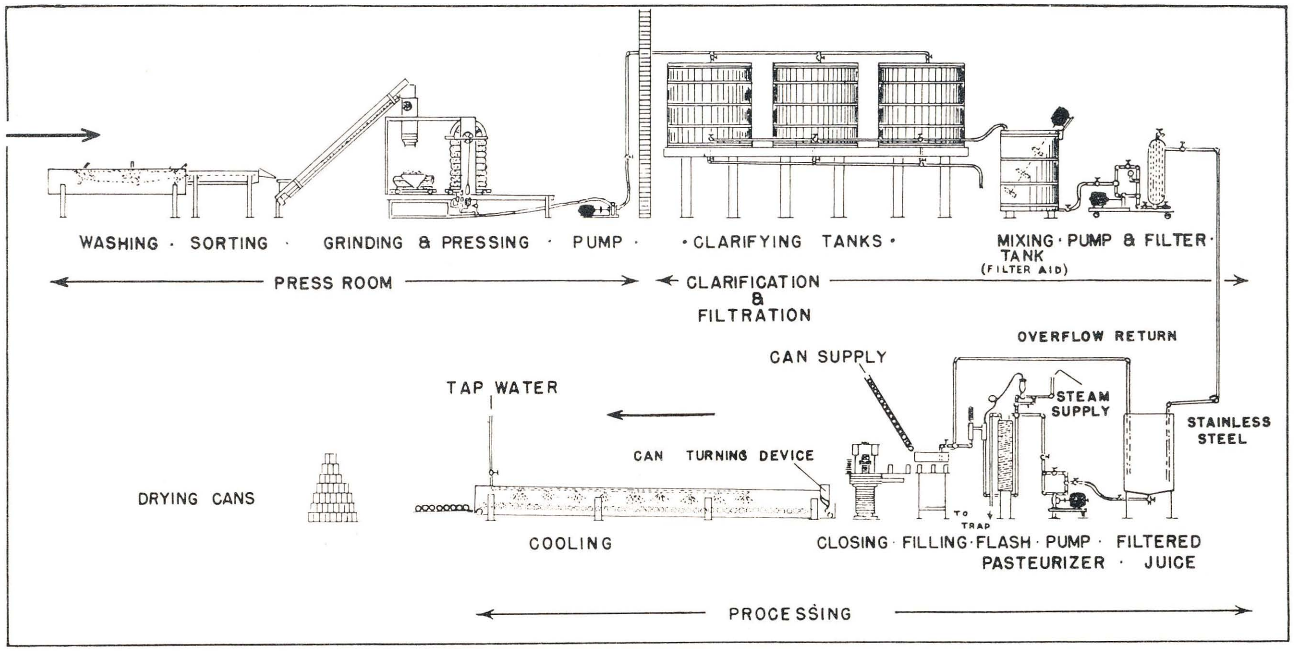

Fig. 29. An illustration of the various steps in the preparation and processing of enzymic clarified apple juice. Modern plants use stainless steel rather than wood tanks.

apples should then be conveyed to a room designed specifically for grinding and pressing operations and the incidental handling of wet pomace, press cloths, racks, and frames. This area is inclined to be rather sloppy and accumulates pieces of pomace and particles of ground apple during operation. This operation should therefore be done in an area that can be separated from processing operations by a wall Another large room should accommodate all of the processing operations from clarification through casing of the filled containers. There should be a room primarily for the boiler, though it may also provide space for a small shop. Finally, there should be a warehouse room for the storage of the finished product. It may also serve as storage space for empty cases and containers.

A single-story building with a high ceiling usually is desirable. It should be well lighted, and provision should be made for ample ventilation. Glazed-tile walls are desirable because they are easily cleaned, long lived, and do not require painting. The floors should be of concrete with a smooth finish to make it easy to maintain them in a strictly sanitary condition. They may be made impervious by adding an asphalt emulsion to the mixture. Floors should have a slope of 2 inches per 10 feet and no part of the floor should be more than 15 feet from a drain. These may be the usual floor drains or they may be flume drains, with metal grating covers constructed in the floor. Such flumes should be not less than 8 inches wide and 5 or 6 inches deep. These drains should be located so that they are under or very close to equipment used for clarification, filtration, pasteurization, and cooling of containers. Water, steam, and electric outlets should be spaced at frequent intervals.

All equipment, except the grinder, press, and can-closing machine, should be mounted on supports with legs to facilitate thorough cleaning of the floor. There should be individual, direct-drive motors, of waterproof construction, for each piece of power-driven equipment. All equipment should be located at least 2 feet from walls and there should be ample clearance provided adjacent to each piece of equipment for operators.

In planning the building and layout it is advisable to make scale cutouts from stiff paper for each item of equipment and then shift these about on the proposed floor plan of the building until the most

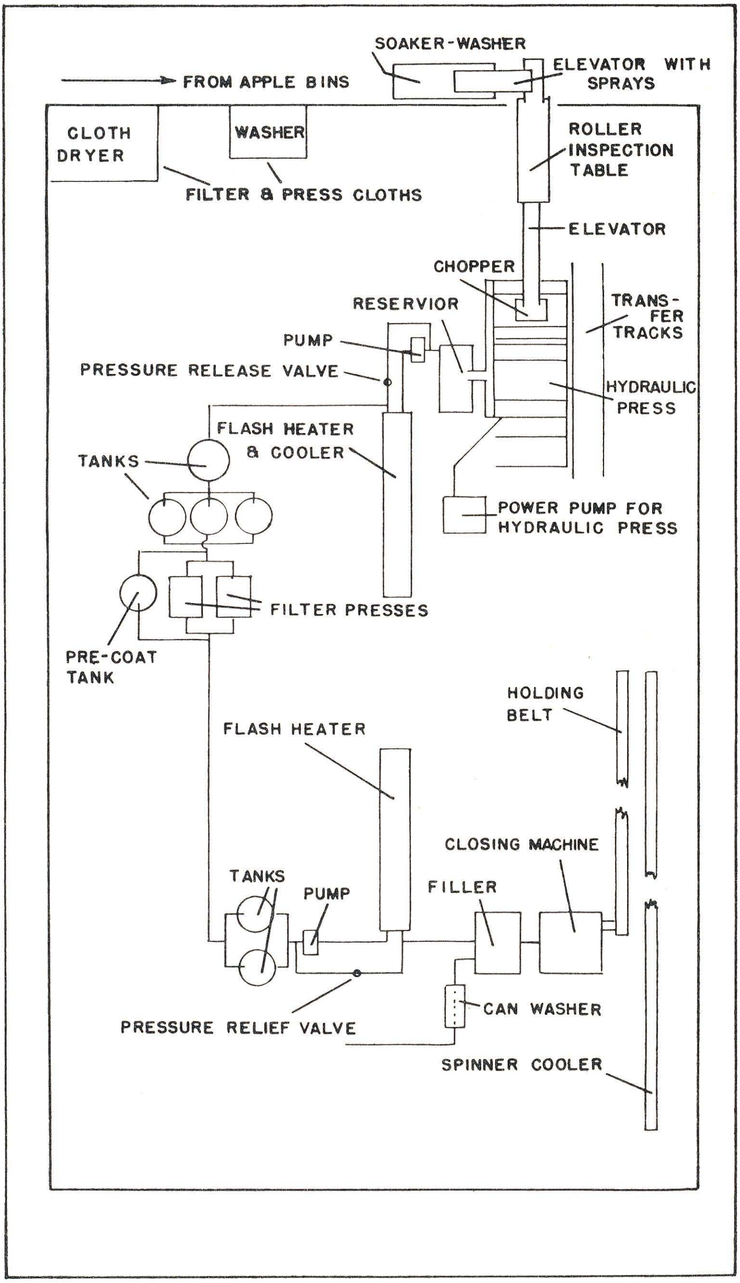

Fig. 30. A floor plan for the preparation and processing of apple juice. A separate room for washing, inspection, grinding, and pressing operations is desirable. (Courtesy Research Department, American Can Co.)

reasonable arrangement is obtained. Then sketch in the arrangement by tracing around the periphery of each piece of equipment and submit the sketch to an architect or contractor for the final development of details.

NUTRITIVE VALUE OF APPLE JUICE

Apple juice, when properly handled and processed, is a delightful, refreshing beverage that appeals to consumers. It must be sold on such a basis and not primarily because of its nutritional properties.

The malic acid in apple juice aids in increasing acidification of gastric contents, which in turn results in better absorption of iron and calcium and promotes digestion of protein materials. The acidity of the juice also helps to reduce gastric bacteria. The pectin that survives the pressing and preparation of the juice serves as a source of uronic acids which act as detoxifying agents. Apple juice compares favorably with other foods having much higher mineral contents because the minerals in apple juice are in highly available forms. Other essential minerals contained in apple juice are calcium, magnesium, potassium, phosphorus, chlorine and sulphur.

Apple juice aids many people troubled with simple constipation. Like other fruit juices, apple juice may be recommended to add variety to the copious quantities of fruit juices often prescribed during illness involving a fever.

The Massachusetts Agricultural Experiment Station has made extensive studies of the vitamin C potency of apple varieties and apple juice, and Clague and Fellers (7) have summarized their findings as follows: Baldwin, Northern Spy, Ben Davis, and Winesap are classified as very good sources of vitamin C (84 to 50 units per ounce); good sources are Esopsus, Rome, King, Roxbury Russet, Rhode Island, and Stayman (48 to 34 units per ounce); those possessing fair amounts (32 to 22 units) per ounce are Arkansas, Gravenstein, Wealthy, Cortland, King David, Golden Delicious, Tolman and McIntosh. They found apples to contain some thiamine and 6 to 7 units of riboflavin per ounce, and assumed that apple juice also contains these vitamins.

More recently, Strachan (23) made a specific study of vitamin C retention in apple juice. He found fresh apple juice to be practically as rich in ascorbic acid as the fresh fruit, and that after 48 hours the juice still retained 70 percent of its ascorbic acid. However, commercially canned juice was found to contain only about 3 percent of the quantity of ascorbic acid found in fresh Newtown apples. It was found that an appreciable amount of ascorbic acid was retained on canning but that it disappeared rapidly during storage until in two weeks or less the ascorbic acid value was only 0.2 milligrams per 100 milliliters. He states that the greatest loss of ascorbic acid in fortified apple juice seems to be due to enclosing air in the head space of the container in the sealing operation. Other studies indicate that each cubic centimeter of air in the head space of the container may destroy one milligram of vitamin C during storage.

The Dominion of Canada required apple juice, during World War II, to contain 35 milligrams of ascorbic acid per 100 milliliters (3.4 ounces) after one year of storage. This usually requires the addition of ascorbic acid at the rate of 50 milligrams per 100 milliliters, or 1.9 grams of crystalline ascorbic acid per gallon of juice, at the time of packing, usually adding it to the batch before flash pasteurization.

Strachan (23) recommends that the juice be deaerated and that the ascorbic acid be added to the juice not more than 15 to 20 minutes prior to flash pasteurization or to each container before filling. Then if the head space air is displaced by nitrogen gas before sealing, as much as 90 percent of the ascorbic acid may be retained after a storage period of 9 months. If usual methods of packing are employed, i.e. filling the containers with non-deaerated juice and enclosing the usual amount of air in the head space, at least 50 percent of the ascorbic acid should be retained after several months' storage.

Since the amount of ascorbic acid loss during storage of fortified juice is about the same quantity regardless of the quantity of ascorbic acid added, the percentage loss is less when greater amounts of ascorbic acid are added. He found that the addition of ascorbic acid had no effect on flavor of the juice, but that it resulted in juice having a lighter color. This color was regarded as too pale when the juice had been clarified with gelatin and tannin.

Esselen, Powers, and Fellers (8) report that some 90 percent of approximately 1,280,000 cases of cloudy apple juice packed in No. 10 cans by the U. S. Army in Australia was fortified with 30 milligrams of ascorbic acid per 100 liters, and that the residual ascorbic acid averaged 27 milligrams or 90 percent. They report that the juice was always lighter in color and of better quality than non-fortified juice.

These investigators also added ascorbic acid at the rate of 50 milligrams to 100 milliliters (190 grams or 6.7 ounces per 100 gallons) of

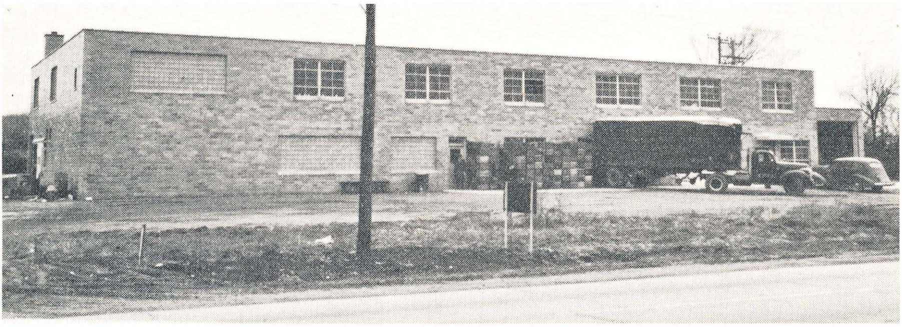

Fig. 31. This building provides for apple juice packing in the left half, and for grading and packing fresh fruit in the right half. Short period holding for apple juice stock is provided in bins immediately back of the first story where there are no windows. Grinding and pressing operations are back of the storage bins with pomace removal at the rear, left door. The processing room is back of the first story glass wall. The second story provides space for storage of empty cans, cases, labels, and fruit packing house supplies. A cold storage joins the back of the building.

flash-heat clarified and filtered apple juice in their laboratories at the Massachusetts Agricultural Experiment Station, and report that this is adequate to provide a juice containing at least 35 milligrams per 100 milliliters after normal distribution to consumers. The reducing action of ascorbic acid retarded darkening in storage. They also found that many consumers seemed to prefer the lighter color caused by ascorbic acid.

Whether it will pay to fortify apple juice, to be consumed in the United States, with ascorbic acid crystals is still open to question. Apparently, it would depend on whether the publicity and promotion campaigns based on such increased nutritive value, together with the better color, would increase demand for apple juice, in competition with other fruit juices, sufficiently to make it a profitable procedure. Canada does not grow citrus fruits and must pay duty on all imports of citrus fruits and their products. Consumers in this country use a variety of fruit juices that supply the necessary vitamin C. If apple juice is to be marketed as a product that will compete with citrus juices as a source of vitamin C, then it must be fortified. If it is fortified, it would seem that crystalline ascorbic acid should be added at the rate of 5 to 6½ ounces per 100 gallons of juice just before flash pasteurization and that the air in the head space should be displaced with nitrogen or carbon dioxide to provide a satisfactory level of vitamin C per serving after the usual storage period. This would be the equivalent of 45 to 58 milligrams of vitamin C per 4 ounces at the time of packing, and it would be safe to claim 30 to 43 milligrams, respectively, per 4 ounces when the juice reaches the consumer.

APPLE JUICE PRODUCTS

Among the products that may be prepared from apple juice are table and industrial syrups and concentrates, apple essence or flavoring extracts, jellies, candies and vinegar. Also, apple pectin may be manufactured from apple pomace. Directions for the manufacture of any one of these products require more space than is justified in a publication such as this, which deals primarily with apple juice. However, the Michigan Agricultural Experiment Station will provide information on this and related subjects on request, or will refer interested parties to reliable sources of information.

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