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AN EVALUATION OF THE TETRA BRIK AS AN ASEPTIC FRUIT JUICE PACKAGE FOR THE UNITED STATES MARKET

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Major professor

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AN EVALUATION OF THE TETRA BRIK AS AN ASEPTIC FRUIT JUICE PACKAGE FOR THE UNITED STATES MARKET

By

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ABSTRACT

AN EVALUATION OF THE TETRA BRIK AS AN
ASEPTIC FRUIT JUICE PACKAGE FOR
THE UNITED STATES MARKET

By

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The economics of the Tetra Brik package are compared to common glass and can packaging. Packaging material and equipment costs along with line layouts are included for juice packers of three different sizes. Potential packaging material savings for a total conversion to the Tetra Brik system are indicated.

Storage testing of clear and unfiltered apple juices was done for 6 months at 100°F. During the first portion of the shelf-life storage test, the Tetra Brik packaged product had a decided quality advantage over canned and bottled juices as a result of the less severe thermal processing. This quality differential decreased with storage time and with some packages reversed itself, the Tetra Brik offering lower quality at the end of 6 months.

Consumer tests of opening and pouring indicate some difficulty with the 1000cc Tetra Brik as compared to cans. Distribution testing shows the Tetra Brik to be very rugged, but it does have a stacking height limitation.

DEDICATED TO
MY WIFE FOR HER
SUPPORT AND ENCOURAGEMENT

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INTRODUCTION

Packages are used to transport, contain, display, preserve and furnish a means of communication to the consumer. Product preservation is most effectively brought about by protection from the ambient environment. This preservation extends the time between the packaging of the product and its ultimate loss of acceptable quality. Shelf-life is the term for the interval during which the product must remain of salable quality while being subjected to the rigors of distribution, storage and consumer handling.

Natural fruit juices are preserved by common packaging in several ways. Tinplate cans prevent the early browning of grapefruit juices through the solution of tin salts in the product. Cans and amber glass offer protection from light which can catalyze juice degradation. A package which has low oxygen permeability can mitigate the effects of polyphenoloxidases in apple juices that have not been thermally processed and thus reduce clouding due to polymerization. Thermal treatments are used to destroy microorganisms within juice. This product, when packaged within a material offering a physical barrier against oxygen permeation and the entry of microorganisms, is shelf-stable.

Fruit juices have been packaged at room temperature in glass bottles and plastic materials such as low density polyethylene. Because of no thermal treatment to destroy the microorganisms capable of spoiling the product, these juices must be distributed and stored under refrigerated conditions.

A shelf-stable juice product can be produced by thermal treatment. In such a process the juice is brought up to and held at an elevated temperature for a specified time. It is then hot filled into packages such as glass bottles or sanitary cans. These are then closed and held for approximately one minute at 186°F prior to initiation of cooling. Spoilage inducing microorganisms present on the packaging material and within the product are destroyed. This product can then be safely held unrefrigerated, in the case of clear apple juice, for a time exceeding two years. Major shortcomings of this method are high packaging costs due to the amount of material required for juice volume and a reduced product quality as a result of extended holding time at an elevated temperature.

A popular method of reducing packaging costs is through either the use of less material or the substitution of lower cost components. For example, glass has been lightweighted to the point where further reductions would result in high losses during filling and distribution. The weight of metal cans has been lowered to the point that any further reduction of material could cause paneling as the vacuum develops after hot filling and might result in axial collapse during rail distribution. Cost effective materials such as paper laminates and polymers are available to replace cans and bottles, but they either lack the required thermal stability to survive heat treatment and the accompanying high moisture levels or do not have the approval of the United States Food and Drug Administration. Acrylonitrile, once viewed as a prime candidate for juice packaging, was removed from the United States marketplace due to concern over monomer migration into the product. Laboratory studies have indicated that this monomer can be carcinogenic.

A method of protecting a moisture and heat sensitive packaging material is to treat the material and product individually by means of a chemical sterilizing agent and heat, respectively. The two are then maintained in a sterile environment during filling and sealing. In this manner, laminates comprised of foil, paperboard and plastics can be used to fabricate a cost effective shelf-stable packaging system. This individual sterilization, followed by combination at filling in a sterile environment, is referred to as aseptic packaging. One such system which has been popular in Europe since 1960 is the Tetra Brik, a rectangular brick-like package made of paperboard/foil/ionomer resin-polyethylene laminate.

The author's interest in such a system is one of potential packaging material cost reductions and possible improvements in product quality. The effects upon juice quality of the less intense thermal treatment offered by the aseptic process will be investigated.

The objective of this thesis is to evaluate the Tetra Brik as an aseptic package for the United States Market. Criteria include economics, initial product quality and after storage testing, consumer utility and the minimizing of package damage which may occur during distribution. While other factors may warrant exploration, the author shall limit the contents of this thesis to the above.

LITERATURE REVIEW

Numerous aseptic filling systems now exist, either in commercial use or under development, for cans, glass bottles, rigid plastic containers, flexible film bags and paper based cartons (3). These systems are limited to liquid products or materials, such as catsup, that can be handled as liquids. In most cases an agent or medium such as hydrogen peroxide or steam is employed to destroy or reduce the number of bacteria present on the packaging material. In others, such as a blown film or bottle, the heat produced for resin conversion is adequate to destroy the microorganisms.

A primary advantage of an aseptic process is that the juice is subjected to a minimum of heat treatment. The product is very quickly heated to the desired pasteurization temperature followed by rapid cooling. Typical values for a clear apple juice are a holding time of 20 seconds at 190-200°F with a 10 second cooldown to 50°F (15). The juice can then be held in an aseptic tank at 50°F until needed for packing.

This is in stark contrast to a hot pack operation where the juice is heated to 198°F and held there for a minimum of one minute (5). It is further held in the filler bowl at this temperature prior to the filling of cans or bottles. The juice provides the necessary heat energy to sterilize the package. Compounding the problem is the overflow return from the filler bowl to the storage tank. Portions of the juice may be heated for upwards of eight hours. The magnitude and duration of this heating coupled with a five minute cooling after packing can result in reduced organoleptic, nutritional and esthetic qualities of the juice (13).

The Europeans may be regarded as the pioneers of aseptic packaging (12). Research on aseptic filling began in the early 1950s with the first aseptic machines installed in Lund and Stockholm in 1952 (26). This was the beginning of a cheaper and more efficient distribution system for milk, particularly in areas where consumers did not have refrigerators.

A descendant of these early aseptic packages is the Tetra Brik, a rectangular paper/foil/polymer carton which is formed, filled and sealed in-line from laminate provided in 150 pound rolls (18). This web stock is first run through a sterilizing fluid which is composed of hydrogen peroxide. The edge of the packaging material is then fitted with a plastic strip to facilitate longitudinal sealing. This seal, done with a combination of hot air and pressure, forms the packaging material into a tube. The sterile juice to be packaged is introduced at 50°F through a stainless steel filling tube into the formed packaging material at a point below the liquid level. This is done to eliminate frothing. Sterilized hot air is constantly being blown into the space above the fluid level to assure that the sterilization of the packaging material is complete. Sealing is done below the surface of the liquid producing a finished package which is completely filled and has no deleterious oxygen containing headspace. The horizontal seal bars contain knives which then cut the formed cartons apart.

The lack of a headspace produces a package which can support compressive loadings not only with its walls, but also with the fluid product which is constrained and considered incompressible. The literature portrays this as obviating the need for a rigid outer box to provide protection during distribution (21). This must be approached with caution because the distribution system of Europe, where the Tetra Brik has been used with much success, typically involves shorter distances and less long term stacking (23).

The shelf-life of products packed in Tetra Brik is in the realm of six to eight months. European packaged milk is reported at six months (4). Sun-Rype of Canada predicts an eight month shelf-life for grapefruit and clarified apple juices (14). These juice products have an initial vitamin C content of 60 mg/100 cc which diminishes to 35 mg/100 cc at the end of eight months (23). The end of shelf-life, in this case, is when the vitamin C content is reduced to 35 mg/100 cc, a Canadian government minimum (15). Other attributes such as flavor and color are still considered satisfactory. It is commonly known that vitamin C reduces the effects of any oxygen which may have been present in the juice upon packing or which reaches the product as a result of inadequate package integrity (13). Go Juice, an orange concentrate available in the United Kingdom, has a six month shelf-life with the aid of added vitamin C (22). To achieve this, it was necessary to add an additional layer of foil and polyethylene to the basic structure which has been used with milk since the 1960s. No information was found on the shelf-life of Tetra Brik packaged fruit juices which had no vitamin C or ascorbic acid added.

The literature search produced no cost comparisons between Tetra Brik and cans or one way glass packaging. Pleeth compared the pint and quart Tetra Brik to returnable glass bottles (10). These data were of no value to the author's economic comparison.

A critical issue to Tetra Brik implementation within the United States was the Food and Drug Administration's non-approval of the hydrogen peroxide sterilizing agent used on the webstock (21). It was thought to have been associated with duodenal cancer (29). Brik Pak of Dallas, Texas filed a petition proposing that the food additive regulations be amended to provide for the use of hydrogen peroxide in combination with a polyethylene packaging material. This was accepted and filed as of July 31, 1979. Brik Pak was awaiting a favorable response during January, 1980. During this interval, the results of a mouse study in Japan were released which looked detrimental to approval (29). However the F.D.A. found the data inconclusive and gave approval for the use of hydrogen peroxide for food packaging when used in contact with polyethylene. This was published in the Federal Register of January 9, 1981.

EXPERIMENTAL

An evaluation of a new or different packaging system requires that the following key points be examined: What are the packaging material costs and what types of equipment are required to run this alternate package? What is the magnitude of capital required for new equipment? Is the system cost effective? What impact will the new package have on product quality and does it have adequate utility and convenience for the consumer? Does the package offer sufficient product protection while being subjected to the rigors of distribution? The following sections explain the methodology used to investigate these issues and technical challenges for the Tetra Brik packaging system.

Determination of Packaging Material and Equipment Costs

Packaging material costs were obtained from vendors supplying the midwestern United States. Order quantities were stated at two million units per buy. This was done to eliminate cost differences which may arise solely due to very large volume purchases. Components were grouped into case quantities which are representative of those found in the marketplace. Total packaging material costs are in Tables 1-4. Costs per ounce of packaged juice are in Figure 1.

Packaging lines were designed and laid out in a style compatible with current commercial practices. See Figures A1-A3. Because the feedstock or apples used to make juice are available only from fall through spring, annual line capacities were calculated assuming a 180 day operation of two shifts. Plants which pack apple juice only, are not operational during the summer months. Capacities are in Table 5.

Canning and bottling line equipment costs were obtained from equipment manufacturers. Installation was not included. Tetra Brik equipment is available by lease only. Line costs are shown in Tables 6-7.

Three fictitious juice packing companies were derived for purposes of economic comparison, Alpha being the smallest, Echo being intermediate in size and Sierra representing the largest. The assumption was made that all product would be packed in Tetra Briks. The 1000 cc Tetra Brik would take the place of the 32 oz. glass bottle and 46 oz. can while the 250 cc Tetra Brik would serve as the single serve package. Volumes and line requirements are shown in Table 8. The ratio of Tetra Brik line capacity to current hot pack volumes was calculated and is shown in Table 8 as a measure of excess production capacity for future expansion or growth. Both the single head AB3 and dual head AB5 Tetra Brik aseptic packagers were used to match production needs with equipment capacity.

Total packaging material and capital equipment costs were calculated by amortization of equipment purchases and Tetra Brik base rental over five years. The base rental is a one time payment. A capital interest loss of 14% was used. Final costs with total annual savings are in Table 9. An example of the calculation method follows:

Alpha Company

Volume = 20 MM, 1000 cc Tetra Briks

Equipment = 1 AB5 dual head aseptic packager with tray packer and shrink tunnel

Packaging Material Cost (from Table 3)

$$\frac{\text{20 MM Tetra Briks}}{\text{12 Tetra Briks/case}} \times \frac{\text{\$0.74 Ttl cost}}{\text{case}} = \text{\$1233M}$$

Equipment Capital (from Table 7)

Total Base Rental

$$\frac{\text{\$451,950}}{\text{5 year amortization}} = \text{\$90.4M}$$

Total Quarterly Rental

$$\frac{\text{\$2,220}}{\text{quarter}} \times \frac{\text{4 quarters}}{\text{year}} = \text{\$ 8.9M}$$

Total Spare Parts

$\frac{\$7{,}045}{\text{5 year amortization}}$	=	\$ 1.4M
Total Capital for Equipment		\$ 101M

Production Rental (from Table 7)

$\frac{\$22.20}{\text{M packages}}$ x 20 MM packages	=	\$ 444M

Capital Interest Loss

\$101M Total Equipment Capital x 14%	=	\$ 14M
Total Packaging Material and Equipment Cost		\$1792M

Sensory Preference and Shelf-Life

Tests were conducted to determine (1) initial product quality of hot filled product compared to Tetra Brik, and (2) storage life of apple juices in Tetra Briks compared to cans and bottles.

One hundred sixty-five gallons each of unfiltered and clear apple juices were prepared in the author's laboratory. No pasteurization was used. The two products were then packed into lined 55 gallon drums and frozen. These were shipped to Raleigh, North Carolina for aseptic packaging into 250 cc Tetra Brik containers. Prior to actual juice packing, the line was run with water to verify seal integrity and to assure the correct placement of the saran tape along the lap seal. The water also served to flush the processing lines of any contaminants.

Equipment adjustments required approximately 20 minutes and 200 packages. The test pack was then conducted. Processing conditions and pack conditions are given in Table 10. Shrink wrapped trays of juice filled Tetra Briks were packed into corrugated shippers, palletized and banded. They were then shipped to the author's laboratory in Minneapolis, Minnesota. Upon arrival all units were inspected for signs of tearing, crushing, abrasion or any other distribution damage. A thorough visual examination showed that none of these defects was present. The packed product was then placed in refrigerated storage at 40°F until the storage testing began.

A 50 gallon portion of each juice which had been shipped to Raleigh was retained as a non-aseptic reference. This was shipped frozen to the Minneapolis laboratory. It was then hot filled into cans and bottles according to the processing conditions in Table 11 and placed into 40°F storage until needed for storage testing. The bottles were clear flint glass with a 38 mm metal screw cap. A can description follows:

<u>5½ oz. Can (202 x 308)</u>

Body: 60# double reduced electrolytic tin plate
Coated with a clear modified vinyl at 13 mg/in^2
Straight wall

Ends: 70# electrolytic tin plate
Zundell ring pull on one end
Coated with a modified vinyl roll coat at 5 mg/in^2
Compounded

<u>46 oz. Can (404 x 700)</u>

Body: 95# electrolytic tin plate
4 beads of 0.050 in. depth
Coated with a modified vinyl roll coat at 5 mg/in^2

Ends: 80# electrolytic tin plate
Plain, must be opened with punch type can opener
Coated with a modified vinyl roll coat at 5 mg/in^2

All cans were tested with an Anderson Company enamel rater (WACO) prior to filling. This instrument measures the electrical current between an electrode attached to the can body and another at the can's center immersed in a 1% sodium chloride solution. The instrument reading in milliamperes gives an indication of the can coating's effectiveness. Readings for the 5½ oz. and 46 oz. cans were less than 10 ma and 30 ma respectively.

A reference standard for all sensory testing was prepared at the same time by limiting the pasteurization to 22 seconds at 190°F. This was cooled over a 10 second interval to 70°F. The product was packed into sterile amber bottles and stored at 40°F.

One thousand cubic centimeter Tetra Briks and reference samples, both cans and bottles, were obtained from B. C. Tree Fruits Incorporated of Kelowna, British Columbia. This was necessary because the test facility at Raleigh, North Carolina was equipped to pack only 250 cc Tetra Briks. B. C. Tree Fruits also provided short pasteurization products in sterile glass bottles to serve as a control.

Shelf-life testing was done for six months at 100°F. All product was placed in the storage cabinet uncased. Fluorescent lighting was on for the duration of the test period. Air circulation was by forced draft. All packages were subjected to a distribution simulation test sequence prior to storage. The compression test to failure was not done because it would have destroyed the packages. This was done later on packages which were not destined for storage testing. Test elements used for the sequential distribution test are in Table 14.

Sensory preference rating tests were conducted each month of the six month storage period by a 30 member trained panel. Samples of each juice and package type were presented at one time to provide a very sensitive test method. This direct or parallel comparison method makes it possible for the panel member to detect very subtle differences among the samples and to taste each as much as necessary, in any chosen order. Samples were compared to the control which had arbitrarily been assigned a value of 20. The judges could assign any value between 1 and 20 for a preference score depending upon the juice's quality. See Figure A6 for the questionnaire format used by the panel members. Test results are in Tables 12-13. These data were also plotted. See Figures 2-5. The mean ($\bar{x}$) and the standard deviation (s) were calculated from these data. From these the F ratio or measure of sample variability was calculated as a means of determining if the difference in the sensory preference ratings over the six month interval was statistically significant.

Consumer Evaluation of Opening Utility

A kitchen practice test was used to determine the relative ease/difficulty with which a Tetra Brik type package can be opened as compared to the standard can pack. Thirty-five respondents were selected from the research and development laboratories of a major food company. The sample included secretaries (20), technicians (8), and maintenance personnel (3) as well as degreed engineers (4). None of these individuals had previously opened a Tetra Brik, but all were very familiar with the references, a 5½ oz. can with Zundell ring pull opener and a 46 oz. can which is opened by piercing the end with a can opener.

The 250 cc Tetra Brik was compared to the 5½ oz. can while the 1000 cc Tetra Brik was compared to the 46 oz. can. Packages were presented to the respondents one at a time. The order was balanced so as not to bias the test by always presenting one type of package, such as the can, first. Respondents were asked to open the 1000 cc Tetra Brik by lifting the side ear and cutting off the tip with scissors. The opened package was then used to fill a glass. The 46 oz. can was opened with a pivoting type, end piercing, can opener. Its contents were also poured into a glass.

The 250 cc Tetra Brik was opened by thrusting an obliquely cut straw through an area delineated on the package.

Questionnaires were provided which required two responses, checking one of seven boxes in a continuum from extremely difficult opening to extremely easy and indicating a preference for either the can or Tetra Brik. See Figure A5.

Responses of opening ease/difficulty were marked on a scale of 1 to 7 with 7 representing the extremely easy end. See Tables A1-A2.

Determination of Susceptibility to Distribution Damage

Given that no Tetra Brik packages could be filled on the evaluation site, it was necessary to test those which had been air shipped from the aseptic packing locations. 250 cc Tetra Brik containers of unprinted bleached kraft were prepared at Raleigh, North Carolina, while the 1000 cc units were fabricated of rotogravure printed bleached kraft at Kelowna, British Columbia. Damage during transit was mitigated by overwrapping the shrink wrapped trays of Tetra Briks with corrugated shippers made of 250 pound B flute material.

Upon arrival at Minneapolis, Minnesota all cases were broken down and visually inspected for any signs of damage as outlined earlier. Those packages which passed the examination were reassembled into fresh corrugated of the same burst value and flute size as originally packed. See Table 3. Tetra Brik trays were again wrapped with polyethylene shrink film.

A distribution test sequence was set up employing the elements of rail and truck shipping as outlined in ASTM D-10 proposed recommended practice, "Performance of Shipping Containers." Elements and levels used for testing the three replicates of each package type are in Table 14. Containers of product were conditioned at 73°F, 50% R.H. for 72 hours in accordance with ASTM D685. Manual handling was tested per ASTM D775 with a Gaynes Engineering free fall drop table. Mechanical vibration testing was done on a Gaynes Engineering orbital vibrating table. No resonance dwell testing was conducted. The test case was placed directly on the table followed by a like case and an appropriate amount of weights to equal the mass of a corresponding pallet stack. The actual weights used are given in Table 16. Inclined impact testing was in accordance with ASTM D880. A backload dolly was loaded with weights equal to approximately 3 lineal feet of like product. See Table 16. Impact velocity was calibrated with an optical velocity sensor with digital readout. Impacts were conducted 50% on the length-height dimension and 50% on the width-height dimension as dictated by pallet orientation. The mechanical handling element was tested by free fall drops onto the steel base of the test equipment. The can and bottle damage which this test produced was greater than that produced in the field, therefore it was concluded that if the Tetra Brik package suffered equal or less damage when subjected to the same conditions, it would prove to be a viable package.

All distribution stressed packages were examined by four different individuals and rated on a scale of 0 to 4, with 0 representing no apparent damage and 4 being damaged to the point of being unsalable or leaking. The rating scale is in Table 15. Barely perceptible damage included very slight denting of cans or glass bottle closures and distortion of Tetra Briks. Minor scuffing of art copy or packaging material was included in this category. Slight damage was identified as denting or distortion which was approximately 1/8 inch deep. Moderate was defined as 1/4 inch. Graphics had to remain legible to be classified moderate. Any damage beyond this was termed unsalable. Damage score frequencies are in Table 17. Scores for individual packages are listed in Tables A3-A7. Compression testing was done in accordance with ASTM D642 to the point of failure on a Tinius-Olson tester at a rate of 1/2 inch per minute. Results are in Table 18.

DATA

Table 1

Glass Packaging Material Costs

Component	Description	Cost/M ($)	Cost/Case ($)
250 cc bottle	flint glass	8.42/gross	1.40
crown	pressed metal	3.25	0.08
label	60# paper	5.50	0.13
carrier	paperboard	82.00	0.33
tray	200# B flute	180.00	0.18
shrink film	2 mil polyethylene		0.03
Total for case of 24			$ 2.15
32 oz. bottle	flint glass	--	--
with reshipper	200# C flute, fiber partitions	20.82/gross	1.74
closure	metal, 38mm	14.73	0.18
label	60# paper	6.32	0.08
Total for case of 12			$ 2.00

Table 2

Can Packaging Material Costs

Description: 3-piece soldered side seam, art copy lithographed on metal, compounded ends. Fabricated of electrolytic tin plate.

Component	Description	Cost/M ($)	Cost/Case ($)
5½ oz can with ring opener end	60# double reduced 70#	63.00	3.02
6 pack carrier	polyethylene	7.58	0.06
Container	175# B flute	116.00	0.12
Total for case of 48			$ 3.20
46 oz. can with ends	95# 80#	220.00	2.64
Container	200# B flute	190.00	0.19
Total for case of 12			$ 2.83

Table 3

Tetra Brik Packaging Material Costs

Component	Description	Cost/M ($)	Cost/Case ($)
250 cc Brik	Flexography	13.50	0.36
Tray	175# B die cut	195.00	0.20
Shrink film	2.5 mil polyethylene	--	0.03
Total for case of 27			$ 0.59
250 cc Brik	Rotogravure	17.00	0.46
Tray	175# B die cut	195.00	0.20
Shrink film	2.5 mil polyethylene	--	0.03
Total for case of 27			$ 0.69
1 liter Brik	Flexography	31.40	0.38
Tray	175# B die cut	210.00	0.21
Shrink film	2.5 mil polyethylene	--	0.04
Total for case of 12			$ 0.63
1 liter Brik	Rotogravure	40.75	0.49
Tray	175# B die cut	210.00	0.21
Shrink film	2.5 mil polyethylene	--	0.04
Total for case of 12			$ 0.74

Table 4

Packaging Material Costs per Ounce of Juice[a]

Package	Cost/Unit ($)	Cost/Ounce (¢)
250 cc glass bottle	0.09	1.1
32 oz. glass bottle	0.17	0.5
5½ oz. can	0.07	1.3
46 oz. can	0.24	0.5
250 cc Tetra Brik Rotogravure	0.03	0.4
1000 cc Tetra Brik Rotogravure	0.06	0.2

[a]Derived from Tables 2 and 3.

Table 5

Packaging Line Capacities

Package	Pkg/min	Pkg/hr.	MM Pkg/180 days-2 shifts
5½ oz. can	360	21,600	62.2
46 oz. can	160	9,600	27.6
250 cc bottle	290	17,400	50.1
32 oz. bottle	75	4,500	13.0
250 cc Tetra Brik	60	3,600	10.4
1000 cc Tetra Brik	60	3,600	10.4

Table 6

Hot Pack Line Equipment Costs

Component	Cost/M ($)
Canning Line	
Depalletizer	25
Filler	38
Seamer	39
Cooler	74
Case packer, sealer	50
Conveyors	20
Change parts	15
Total	$ 261 M
Bottling Line	
De-caser	19
Washer, pre-heater	19
Filler	62
Capper	22
Cooler	74
Labeler	18
Coder	12
Case packer	31
Case sealer	15
Conveyors	30
Total	$ 302 M

Table 7

Tetra Brik Line Equipment Costs

SUPPORT EQUIPMENT	Cost
Positive Atmosphere Room	$ 300M
VHT Heat Exchanger	80
Aseptic Tank	105
Total	$ 485M

LINE EQUIPMENT	Base Rental	Quarterly Rental	Spare Parts	Production rental/M ($)
10.4MM Annual Capacity				
AB3 Brik Pak	189,300	1,050	3,140	250cc-10.90 1000cc-22.20
Tray packer	41,050	125	415	0
Shrink tunnel	30,850	90	415	0
Total	$261,200	$1,265	$3,970	$10.90/22.20
20.8MM Annual Capacity				
AB5 Brik Pak	339,000	1,880	5,800	250cc-10.90 1000cc-22.20
Tray packer (2)	82,100	250	830	0
Shrink tunnel	30,850	90	415	0
Total	$451,950	$2,220	$7,045	$10.90/22.20

Table 8

Lines Required to Meet Pack Requirements of Alpha, Echo and Sierra Companies

Company	Package	Units (MM)	No. Lines	Line Capacity / Current Volume
ALPHA	5½ oz. can	27	0.63	1.45
			1	
Hot Pack	46 oz. can	7	0.37	1.45
	32 oz. bottle	11	1	1.18
Aseptic	250 cc Brik	18	1 (AB5)	1.16
	1000 cc Brik	20	1 (AB5)	1.04
ECHO	5½ oz. can	100	2	1.24
Hot Pack	46 oz. can	55	2	1.00
	32 oz. bottle	80	7	1.14
Aseptic	250 cc Brik	65	3 (AB5) 1 (AB3)	1.12
	1000 cc Brik	151	8 (AB5)	1.10
SIERRA	5½ oz. can	225	4	1.11
Hot Pack	46 oz. can	150	6	1.10
	250 cc bottle	180	4	1.34
	32 oz. bottle	80	7	1.14
Aseptic	250 cc Brik	326	18 (AB5)	1.15
	1000 cc Brik	280	15 (AB5)	1.11

Table 9

Can and Bottle Packaging Material and Equipment Cost Comparison to Tetra Brik

Company	Package	Pkg. Mat'l Cost ($M)	Equipment Capital ($M)	Production Rental ($M)	Total[a] ($M)
ALPHA	5½ oz. can	1,800	33	0	1,838
	46 oz. can	1,651	19	0	1,673
	32 oz. glass	1,833	60	0	1,901
	Total	5,284			5,412
	250 cc Brik	460	101	196	771
	1000 cc Brik	1,233	101	444	1,792
	Total	1,693			2,563
	Savings				2,849
ECHO	5½ oz. can	6,667	104	0	6,786
	46 oz. can	12,970	104	0	13,089
	32 oz. glass	13,333	423	0	13,815
	Total	32,970			33,690
	250 cc Brik	1,661	361	709	2,781
	1000 cc Brik	9,311	808	3,352	13,584
	Total	10,972			16,365
	Savings				17,325
SIERRA	5½ oz. can	15,000	209	0	15,238
	46 oz. can	35,375	313	0	35,732

Table 9 (cont'd.)

Company	Package	Pkg. Mat'l Cost ($M)	Equipment Capital ($M)	Production Rental ($M)	Total[a] ($M)
	250 cc bottle	16,125	242	0	16,401
	32 oz. bottle	13,333	423	0	13,815
	Total	79,833			81,186
	250 cc T.B.	8,331	1,818	3,553	13,956
	1000 cc T.B.	17,266	1,515	6,216	25,209
	Total	25,597			39,165
	Savings				42,021

[a]Includes 14% capital interest loss.

Table 10

North Carolina State University Juice Processing Conditions

Initial condition:	Five day thaw at 36°F.
Feed volume:	110 gallons/batch
Pasteurization:	22 seconds at 190°F with steam heated shell and tube exchanger.
Cooling:	10 seconds from 190°F to 70°F with ice water cooled shell and tube heat exchanger.
Fill temperature:	70°F.
250 cc units packed:	1500/batch
Flow rate:	238 gallons/hour at Tetra Brik machine.

Table 11

Laboratory Juice Processing Conditions

Initial condition:	One day thaw at 40°F.
Feed volume:	35 gallons/product.
Pasteurization:	60 second minimum at 198°F with steam heated plate exchanger.
Cooling:	1 minute at ambient, 70°F followed by 6 minutes in tapwater raining station.
Filling temperature:	186°F
Units packed:	220 5½ oz. cans 40 46 oz. cans 40 32 oz. bottles

Table 12

Sensory Preference of Packaged Clear Apple Juice

Time (Months)	250cc Brik	1000cc Brik	5½oz. can	46oz. can	32oz. bottle
0	19	20	18	17	17
1	19	19	17	17	16
2	18	20	17	16	17
3	16	19	17	17	16
4	17	16	16	16	17
5	15	17	17	15	15
6	13	15	17	16	15
Mean ($\bar{x}$)	16.7	18.0	17.0	16.3	16.1
Std.Dev. (s)	2.2	2.0	0.6	0.2	1.6

F ratio (F) = $\frac{(s_1)^2}{(s_2)^2}$ = 13.4
250cc/5½oz.

F = 100.0
1000cc/46oz.

F = 1.6
1000cc/32oz.

1 = dislike extremely
20 = like extremely

Table 13

Sensory Preference of Packaged Unfiltered Apple Juice

Time (Months)	250cc Brik	1000cc Brik	5½oz. can	46oz. can	32oz. bottle
0	19	18	17	18	17
1	17	18	18	17	16
2	17	19	17	16	16
3	16	18	17	16	14
4	15	16	16	17	15
5	12	14	17	15	13
6	11	14	16	15	12
Mean ($\bar{x}$)	15.3	16.7	16.9	16.3	14.7
Std. Dev. (s)	2.9	2.1	0.7	1.1	1.8

F ratio (F) $= \frac{(s_1)^2}{(s_2)^2} =$ 17.1 250cc/5½oz.

F = 3.6 1000cc/46oz.

F = 1.36 1000cc/32oz.

1 = dislike extremely
20 = like extremely

Table 14

Sequential Test Data

Hazard	Test	Level
Manual handling	Free fall drop	Two drops at 27 inches
Vibration	Mechanical vibration	3 Hz at 1g for 5 minutes
Rail switching	Conbur inclined plane	10 impacts at 8 mph
Mechanical handling	Free fall drop	Five drops at 15 inches
Vehicle, warehouse stacking	Compression	Failure

Table 15

Sequential Rating Scale

0	No apparent damage
1	Barely perceptible damage
2	Slight damage
3	Moderate but yet saleable
4	Damaged to a point of being unsaleable or leaking

Table 16

Sequential Test Loading Data

Package	Weight (lbs.)	Pallet stack weight (lbs.)	Backload (lbs.)
5½ oz. can	21.2	170	42
46 oz. can	38.0	304	76
32 oz. glass	30.0	240	60
250 cc Tetra Brik	17.0	136	34
1000 cc Tetra Brik	28.5	228	57

Table 17

Damage Score Frequency for Sequential Test Packages

Package	Number Tested	Damage Score				
		0	1	2	3	4
5½ oz. can	144	0	51	80	13	0
46 oz. can	36	0	1	17	18	0
32 oz. glass bottle	36	29	4	0	0	3
250 cc Tetra Brik	81	3	22	36	20	0
1000 cc Tetra Brik	36	0	4	18	13	1

Table 18

Package Compression Data

Package		Compression at Failure (Lbs) 3 determinations
48/5½ oz. can		
		17,900
		20,500
		18,700
	Mean $(\bar{x})$ =	19,000
12/46 oz. can		
		14,900
		12,800
		14,800
	Mean $(\bar{x})$ =	14,200
12/32 oz. glass		
		5,400
		4,900
		6,500
	Mean $(\bar{x})$ =	5,600
4/1 gal.		
		20,200
		16,700
		15,900
	Mean $(\bar{x})$ =	17,600
27/250 cc Tetra Brik		2,100
		1,600
		2,200
	Mean $(\bar{x})$ =	2,000
12/1 1 Tetra Brik		
		1,800
		1,600
		1,500
	Mean $(\bar{x})$ =	1,600

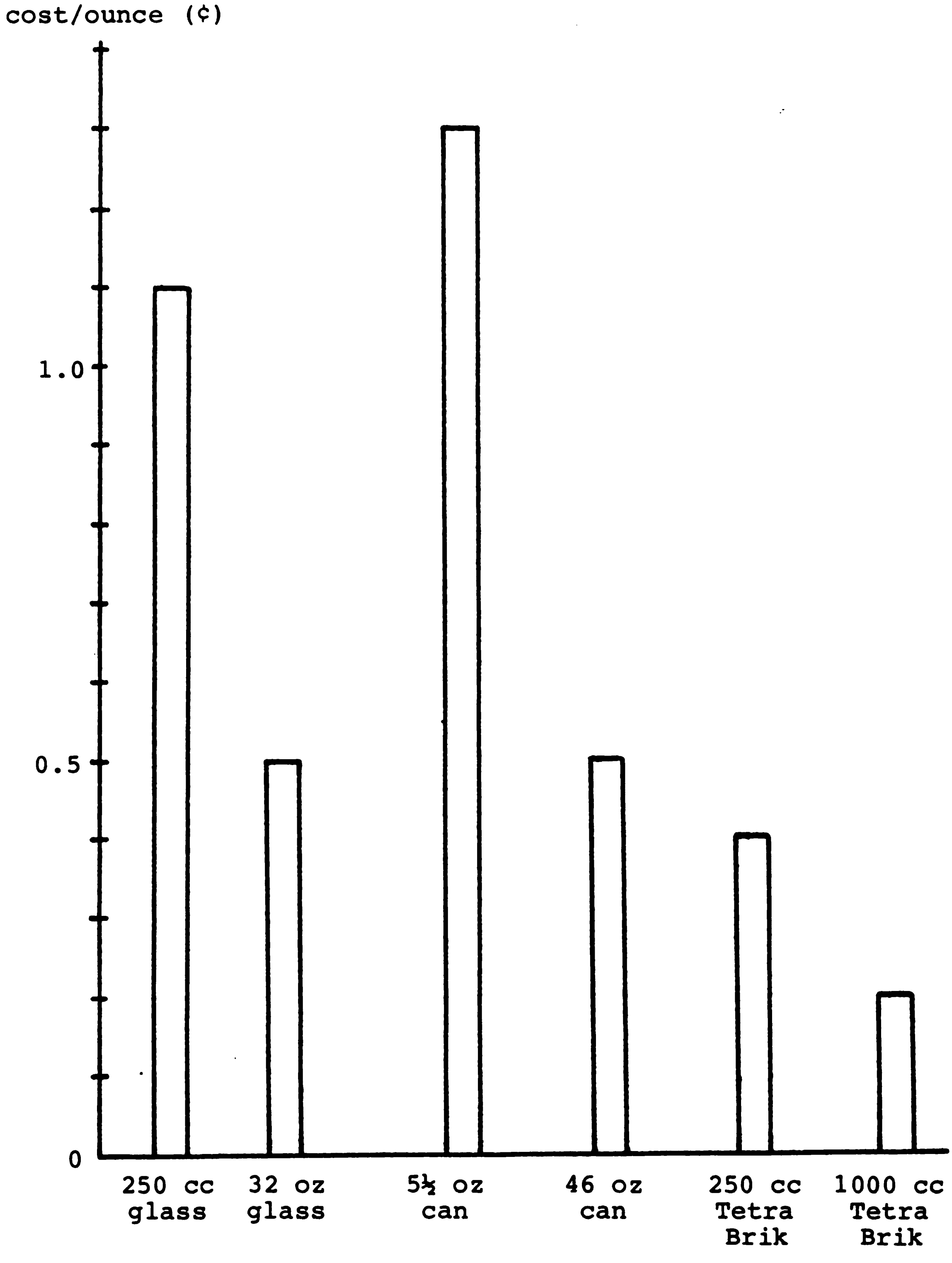

Figure 1. Packaging material costs per ounce of juice

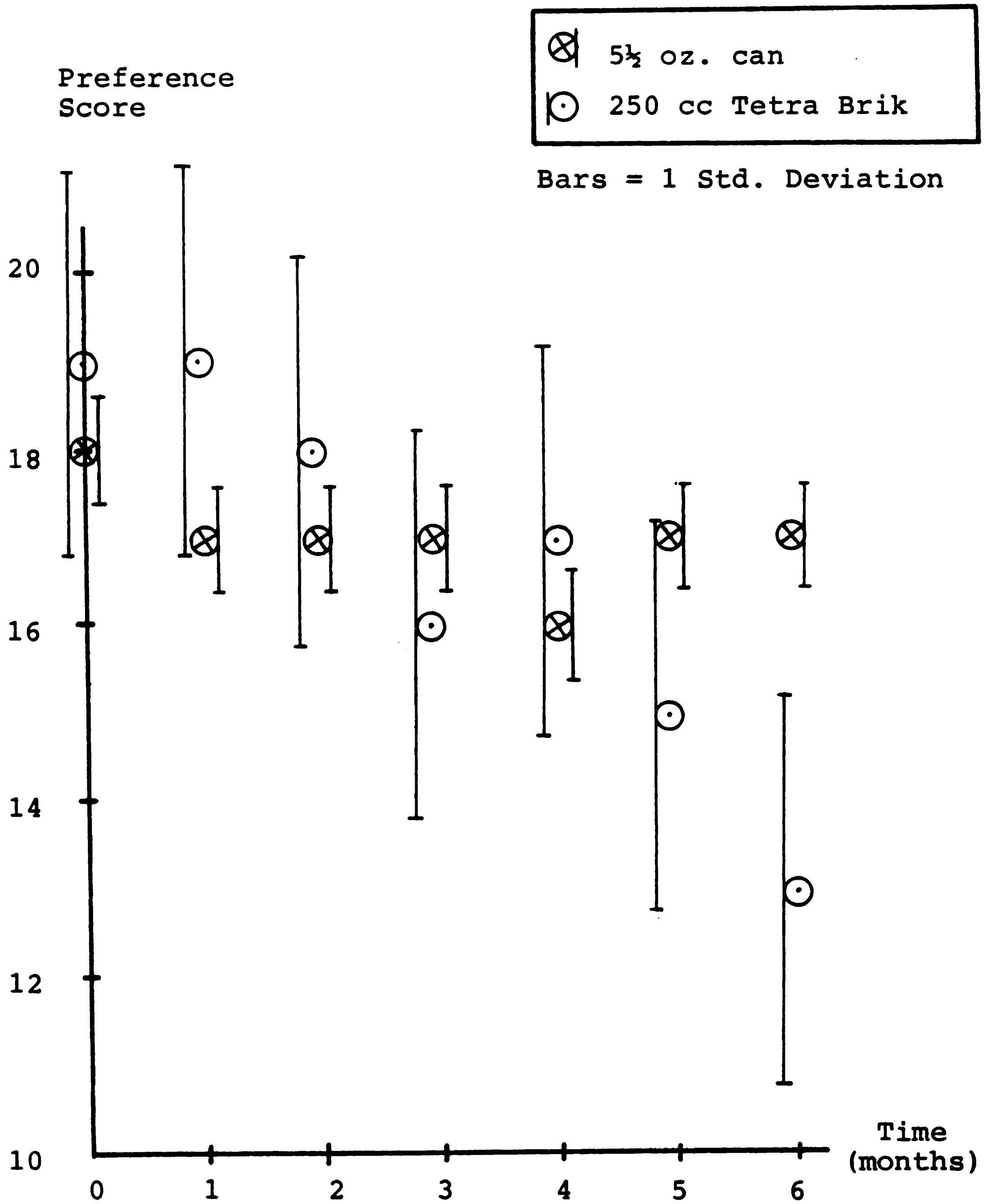

Figure 2. Sensory preference score vs. time for clear apple juice in single serve packages

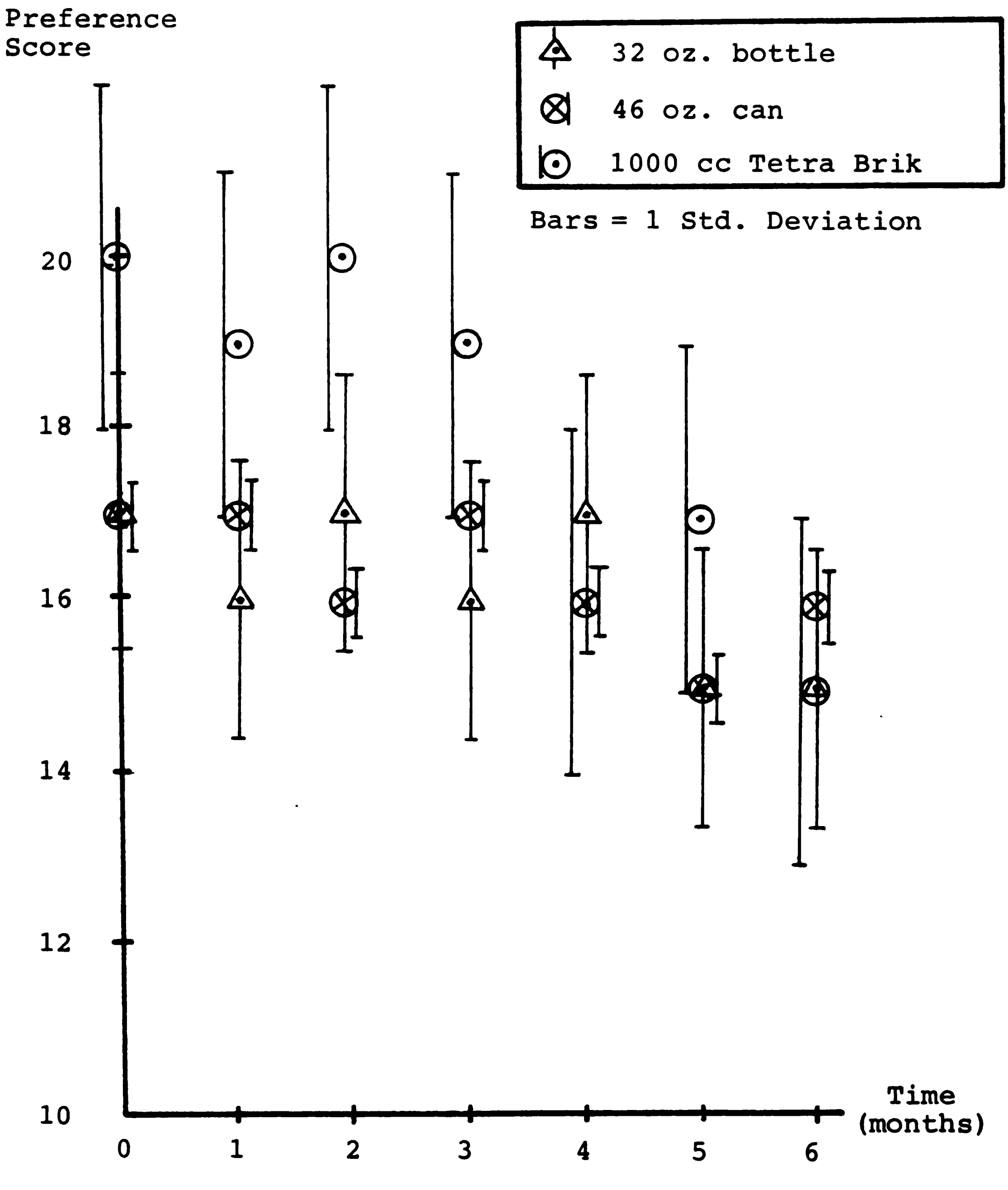

Figure 3. Sensory preference score vs. time for clear apple juice in multi-serve packages.

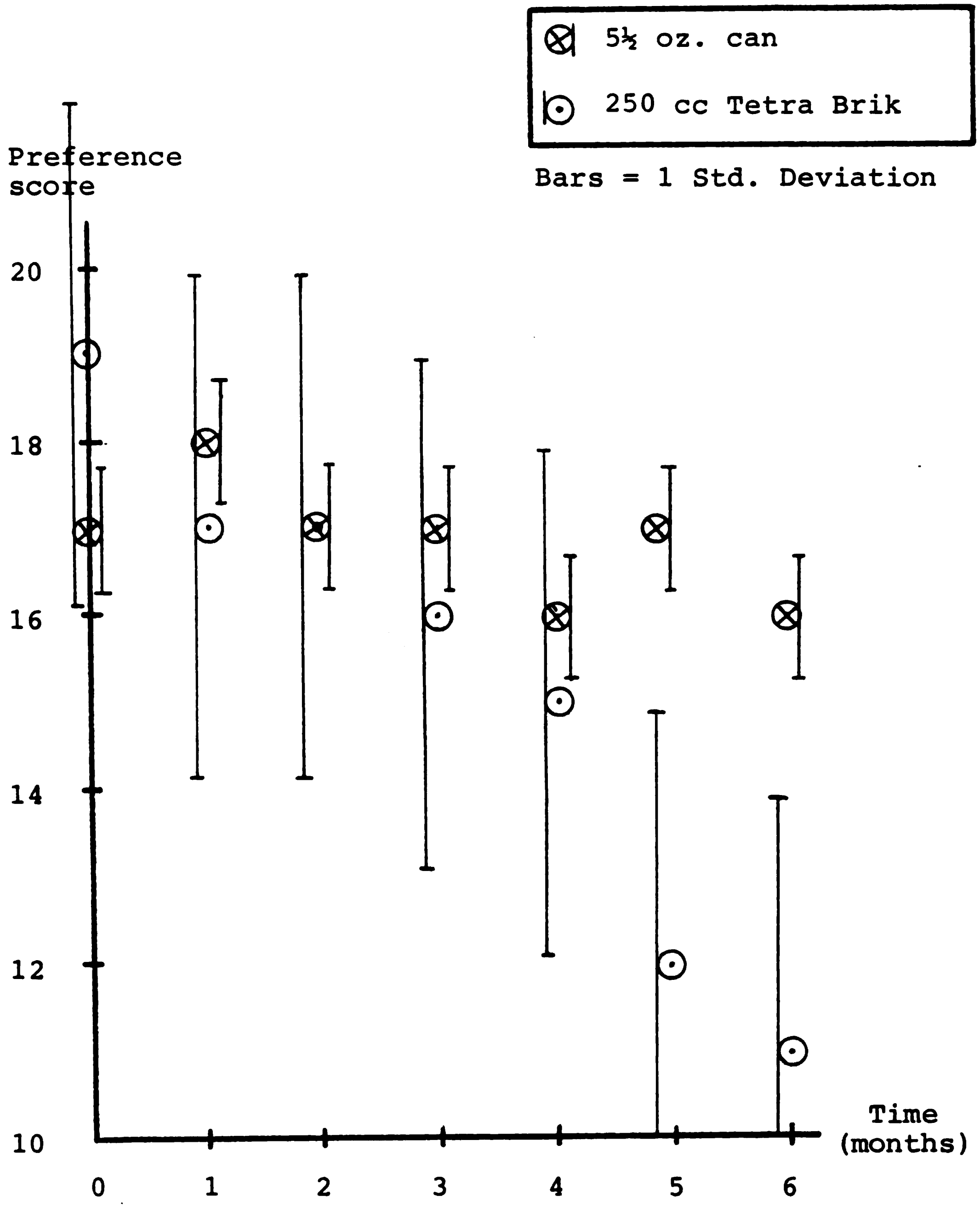

Figure 4. Sensory preference score vs. time for unfiltered apple juice in single serve packages

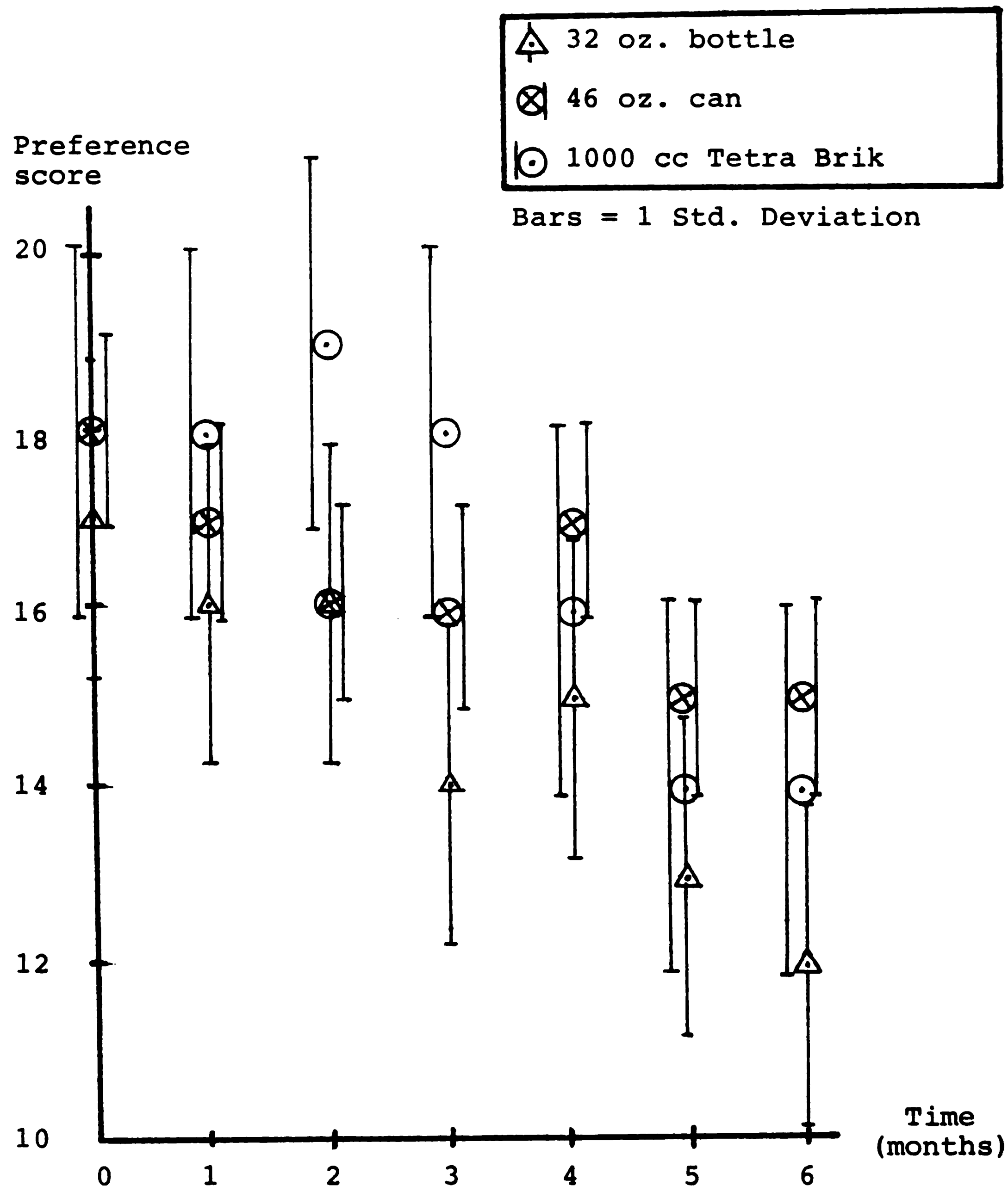

Figure 5. Sensory preference score vs. time for unfiltered apple juice in multi-serve packages

DISCUSSION AND CONCLUSION

A review of Tables 1-4 and Figure 1 shows the significant differences in packaging material costs when comparing the Tetra Brik to conventional cans and bottles. The 5½ oz. can is the most expensive per unit volume of juice while the 1000 cc Tetra Brik is the least expensive package. The packaging material cost per ounce of juice for these two containers is 1.3 and 0.2 cents, respectively. When one considers that the total production cost of 48 5½ oz. cans of juice is approximately $6.00, the packaging materials alone will represent 53% of that total. The consumer will discard $0.07 worth of materials after consuming 5½ oz. of juice. When using the 250 cc Tetra Brik this diminishes to approximately $0.03.

More lines are required to meet pack volumes when implementing the Tetra Brik system. This is because of the greatly reduced speeds in contrast to canning and bottling lines. Table 5 shows a range of 360/minute for the 5½ oz. can to 60/minute for both the 250 cc and 1000 cc Tetra Briks. Table 8 lists the number of lines required when making the conversion from hot pack. Here it is shown that the largest of the three juice packers, the Sierra Company, must go from 21 to 33 lines, an increase of

12. While on the surface this may seem catastrophic, an annual savings of $42MM is realized which offsets the costs of expansion. The Alpha Company, the smallest packer listed in Table 8, can also find the transition profitable with an annual savings of $2.8MM.

While not within the defined scope of this thesis, it can be shown that further economies are available through reduced shipping weight, smaller finished product volume, diminished warehousing space and a reduction in line personnel.

The juice quality prior to storage testing at 100°F was found to differ significantly. All samples packed in Tetra Briks produced a higher preference rating as shown in Figures 2-5. This is in concurrence with the different processing conditions of Tables 10 and 11.

Storage, however, produced a quality degradation in the Tetra Brik product which progressed at a faster rate than that of the canned or bottled product. Figure 2 shows a curve intersection for clear juice in single serve packages at approximately three months. Beyond this point the Tetra Brik juice quality falls off rapidly. A possible explanation is that the packaging material of the Tetra Brik is permitting oxygen to permeate the package walls and act upon the juice. This can result from manufacturing or fabrication defects as well as flex cracking produced during distribution simulation. The cans and bottles are considered impermeable to oxygen. If oxygen did enter these packages, it would be at the bottle closure or at a defective side-seam or improperly seamed end on the can. The clear juice in the multi-serve Tetra Brik fared much better than the 250 cc unit. As shown in Figure 3 the Tetra Brik and can curves intersect at about six months. This slower product degradation in the 1000 cc Tetra Brik as compared to the 250 cc Tetra Brik can best be explained by a lower area/volume ratio of the 1000 cc package. This reduces the oxygen uptake by the product. The overall quality of the unfiltered juice decreased at a faster rate than did that of the clear juice. A comparison of Figures 2 and 4 shows that the clear juice 250 cc Tetra Brik curve intersects the 5½ oz. can curve at approximately three months, whereas this same intersection occurred with unfiltered juice at approximately two months. An examination of Figures 3 and 5 gives further evidence that the unfiltered product is more sensitive to the effects of the storage test than the clear juice. The clear juice in 1000 cc Tetra Briks decreased in quality to that of the canned product at six months. This same change occurred with the unfiltered juice after 4½ months. The effects of light upon this juice are very evident from Figure 5.

Based on this testing, at 9 months the 1000 cc Tetra Brik would deliver both products to the consumer at a quality level which is comparable to that of the 32 oz.

bottle or 46 oz. can. The 250 cc Tetra Brik would not meet the quality levels achievable with the 5½ oz. can, but would approach that of the 32 oz. bottle and 46 oz. can.

The F score or measure of sensory score variation among samples over the six month storage period showed that with the clear juice there was a statistically significant difference in both the 250 cc Tetra Brik vs. 5½ oz. can comparison and the 1000 cc Tetra Brik vs. 46 oz. can comparison. The unfiltered juice indicated a significant difference only when comparing the 250 cc Tetra Brik with the 5½ oz. can. These values are given in Tables 12-13. The above differences were significant at the 1% level.

Possible errors exist in the sensory testing methodology in that the laboratory hot pack simulation does not exactly match that of a production plant. Juice holding, filling and cooling times may differ greatly from what what done in the laboratory. While packing the product in a juice plant may be ideal, it was out of the question due to the juice volume required and the difficulty of obtaining line time. A distinct advantage of the laboratory approach, as used by the author, was that exactly the same juice feed stock used for the aseptic packages was used to produce the can and bottle hot pack samples.

Consumer evaluation of the packages' utility produced mixed results. A comparison of the opening ease of the 250 cc Tetra Brik against the 5½ oz. can produced no statistically significant difference. Twenty-three of the 35 respondents indicated a preference for the Tetra Brik package. The 1000 cc Tetra Brik was rated significantly more difficult to use than the 46 oz. can. Twenty-four of the 35 respondents preferred the can. The primary difficulties arose when the consumer squeezed the package at the time of opening or pouring. Because there is no headspace, the liquid contents rise over the cut opening spilling onto the work surface.

Scores for the sequential tests show that the damage suffered by the Tetra Briks was not significantly different from that of the cans and bottles. One aseptic package, a 1000 cc Tetra Brik, was scored at 4 due to rupture. Examination showed poor adhesion of the sealants in the long seal area. Very extensive research under production conditions would be needed to determine the frequency of such a failure. This is in the realm of further work.

The ability to support compressive loads was less than conventional packaging. A case of 250 cc Tetra Briks fails at 2,000 lbs., whereas 5½ oz. cans can endure upwards of 19,000 lbs. This load bearing capacity is very important because common warehousing practices are such that pallets are often stacked three and four high for maximum space utilization. Taking the data from Table 18 and assuming a stacking safety factor of 5, stack loads of 400 lbs. and 320 lbs. are derived for the 250 cc and 1000 cc Tetra Briks, respectively. This translates to a maximum pallet stack height of 2. Common industry practice is to stack pallets three or four high. The use of warehouse racks is recommended for better space utilization and the safeguarding of package integrity. An alternate solution is the upgrading of the combination tray-shipper to a higher test corrugated board such as double wall with vertical partitions between the Tetra Briks.

The test sequence that was used cannot be said to duplicate the shipping environment, but it does serve to compare the Tetra Brik to existing packages. The data thus derived indicates that the Tetra Brik would function in such a distribution system provided the above restrictions on stacking were adhered to.

SUMMARY

It has been shown that substantial packaging material economies can be had when using the Tetra Brik. Further benefits, in the form of superior product quality, are obtained during the first portion of the juice's shelf-life. The total shelf-life is reduced to five or six months, but this poses no problem to a juice packer that can modify its production scheduling and inventory control to accommodate this new package. However, a very small packer that must rely on the two year shelf-life of canned and bottled juices to maintain its inventory will find the Tetra Brik unacceptable.

Consumer handling problems were discovered when testing the 1000 cc Tetra Brik. The author feels that this can be overcome through familiarization with the package. An area in which further work needs to be done is that of consumer acceptance at the retail level.

As currently packaged, the Tetra Brik cannot be stacked as high as common can and glass containers. Two pallets high is the limit with warehousing racks preferred.

Several food packers in the United States are now doing research on the Tetra Brik. At some of these locations packing lines have been installed. These firms want to be ready to introduce a packaging concept which is new to the United States market.

APPENDIX

APPENDIX

Table A1

Consumer Response for 250 cc Tetra Brik
Opening and Drinking Evaluation

Respondent	Score (1=difficult, 7=easy) 5½ oz. Can	250 cc Tetra Brik	Preference
1	5	7	brik
2	3	5	brik
3	5	5	brik
4	4	6	brik
5	4	5	brik
6	7	4	can
7	4	6	brik
8	2	5	brik
9	4	5	can
10	7	3	can
11	4	4	can
12	3	5	can
13	4	5	brik
14	7	6	can
15	3	6	brik
16	7	6	brik
17	3	4	brik

Table A1 (cont'd.)

Respondent	Score (1=difficult, 7=easy) 5½ oz. Can	250 cc Tetra Brik	Preference
18	6	7	can
19	2	6	brik
20	3	5	brik
21	4	6	brik
22	5	7	brik
23	6	6	can
24	7	7	can
25	3	5	brik
26	5	5	brik
27	6	4	can
28	4	6	brik
28	3	6	brik
30	7	7	brik
31	4	4	brik
32	6	3	can
33	3	7	brik
34	5	5	brik
35	7	3	can
Mean ($\bar{x}$) =	4.6	5.3	can = 12 brik = 23
Standard Deviation (s) =	1.7	1.7	

Table A2

Consumer Responses for one Liter Tetra Brik Opening and Pouring Evaluation

	Score (1=difficult, 7=easy)		
Respondent	46 oz. Can	1000 cc Tetra Brik	Preference
1	6	5	can
2	7	3	can
3	4	5	brik
4	6	2	can
5	6	4	can
6	5	3	can
7	7	1	can
8	6	4	can
9	5	3	can
10	5	6	brik
11	7	3	can
12	6	6	brik
13	7	4	can
14	5	2	can
15	6	3	can
16	5	5	brik
17	6	7	brik
18	5	3	can
19	4	5	brik
20	6	6	can

Table A2 (cont'd.)

Respondent	Score (1=difficult, 7=easy) 46 oz. Can	1000 cc Tetra Brik	Preference
21	7	6	can
22	5	6	brik
23	6	3	can
24	7	2	can
25	6	4	can
26	7	4	can
27	3	6	brik
28	5	5	brik
29	5	3	can
30	7	6	brik
31	7	4	can
32	6	6	brik
33	6	1	can
34	6	3	can
35	7	2	can
Mean (x) =	5.8	4.3	can = 24 brik = 11
Standard Deviation (s) =	1.17	0.64	

Table A3

Sequential Test Scores for 5½ oz. Can

	Damage Score (0=none, 4=leakage)		
Can No.	Case 1	Case 2	Case 3
1	2	3	1
2	1	1	2
3	2	2	2
4	2	3	3
5	1	1	1
6	1	2	2
7	2	1	2
8	3	2	1
9	2	2	2
10	2	1	1
11	1	2	2
12	1	2	1
13	2	2	1
14	2	1	1
15	3	2	2
16	2	2	3
17	1	2	2
18	2	3	2
19	1	1	1
20	2	2	1
21	3	2	2
22	2	1	2
23	1	2	3
24	2	2	1
25	1	3	1
26	1	2	1
27	1	1	2

Table A3 (cont'd.)

Can No.	Damage Score (0=none, 4=leakage) Case 1	Case 2	Case 3
28	2	2	2
29	1	2	2
30	1	2	2
31	1	2	1
32	2	1	1
33	1	2	2
34	2	2	1
35	1	2	2
36	1	2	2
37	1	3	1
38	2	2	3
39	1	2	2
40	2	2	2
41	1	2	1
42	2	2	2
43	1	2	2
44	2	2	2
45	2	1	2
46	3	1	1
47	1	2	2
48	1	2	2
Mean ($\bar{x}$) =	1.6	1.9	1.7

Table A4

Sequential Test Scores for 46 oz. Can

	Damage Score (0=none, 4=leakage)		
Can No.	Case 1	Case 2	Case 3
1	3	2	3
2	2	3	3
3	2	3	2
4	3	2	2
5	3	3	3
6	2	2	1
7	3	2	3
8	2	3	3
9	2	2	2
10	3	2	3
11	3	2	2
12	3	3	2
Mean ($\bar{x}$) =	2.6	2.4	2.4

Table A5

Sequential Test Scores for 32 oz. Glass Bottle

	Damage Score (0=none, 4=leakage)		
Bottle No.	Case 1	Case 2	Case 3
1	0	0	1
2	0	1	0
3	0	0	0
4	0	0	4
5	0	0	0
6	0	1	0
7	0	0	0
8	0	0	0
9	0	0	0
10	4	0	0
11	4	0	0
12	1	0	0
Mean ($\bar{x}$) =	0.8	0.2	0.4

Table A6

Sequential Test Scores for 250 cc Tetra Brik

	Damage Score (0=none, 4=leakage)		
Package No.	Case 1	Case 2	Case 3
1	3	3	2
2	2	3	2
3	2	1	1
4	2	1	2
5	1	0	2
6	2	2	1
7	2	1	3
8	3	2	2
9	3	3	2
10	3	2	3
11	1	2	2
12	0	1	2
13	0	1	3
14	1	2	3
15	1	2	3
16	1	1	2
17	1	2	1
18	1	3	3
19	3	2	2
20	2	2	3

Table A6 (cont'd.)

Package No.	Damage Score (0=none, 4=leakage)		
	Case 1	Case 2	Case 3
21	3	1	3
22	2	2	2
23	2	1	1
24	2	2	1
25	1	2	2
26	1	2	2
27	3	3	2
Mean ($\bar{x}$) =	1.8	1.8	2.1

Table A7

Sequential Test Scores for 1000 cc Tetra Brik

	Damage Score (0=none, 4=leakage)		
Package No.	Case 1	Case 2	Case 3
1	3	2	3
2	2	2	2
3	2	1	2
4	2	2	3
5	3	2	3
6	3	2	4
7	2	3	3
8	2	2	2
9	3	1	1
10	1	3	2
11	2	2	3
12	2	3	3
Mean ($\bar{x}$) =	2.3	2.1	2.6

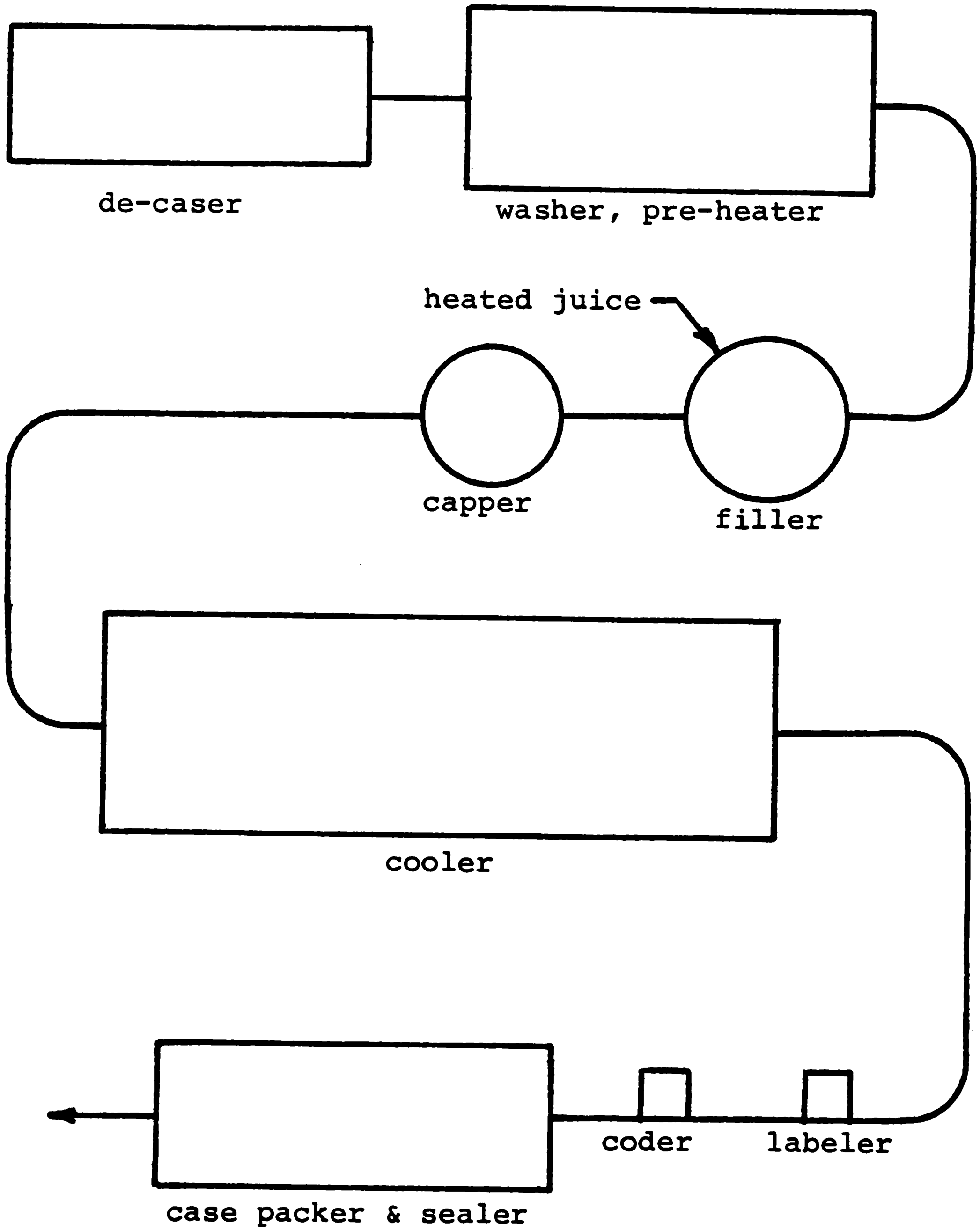

Figure A1. Bottling line layout

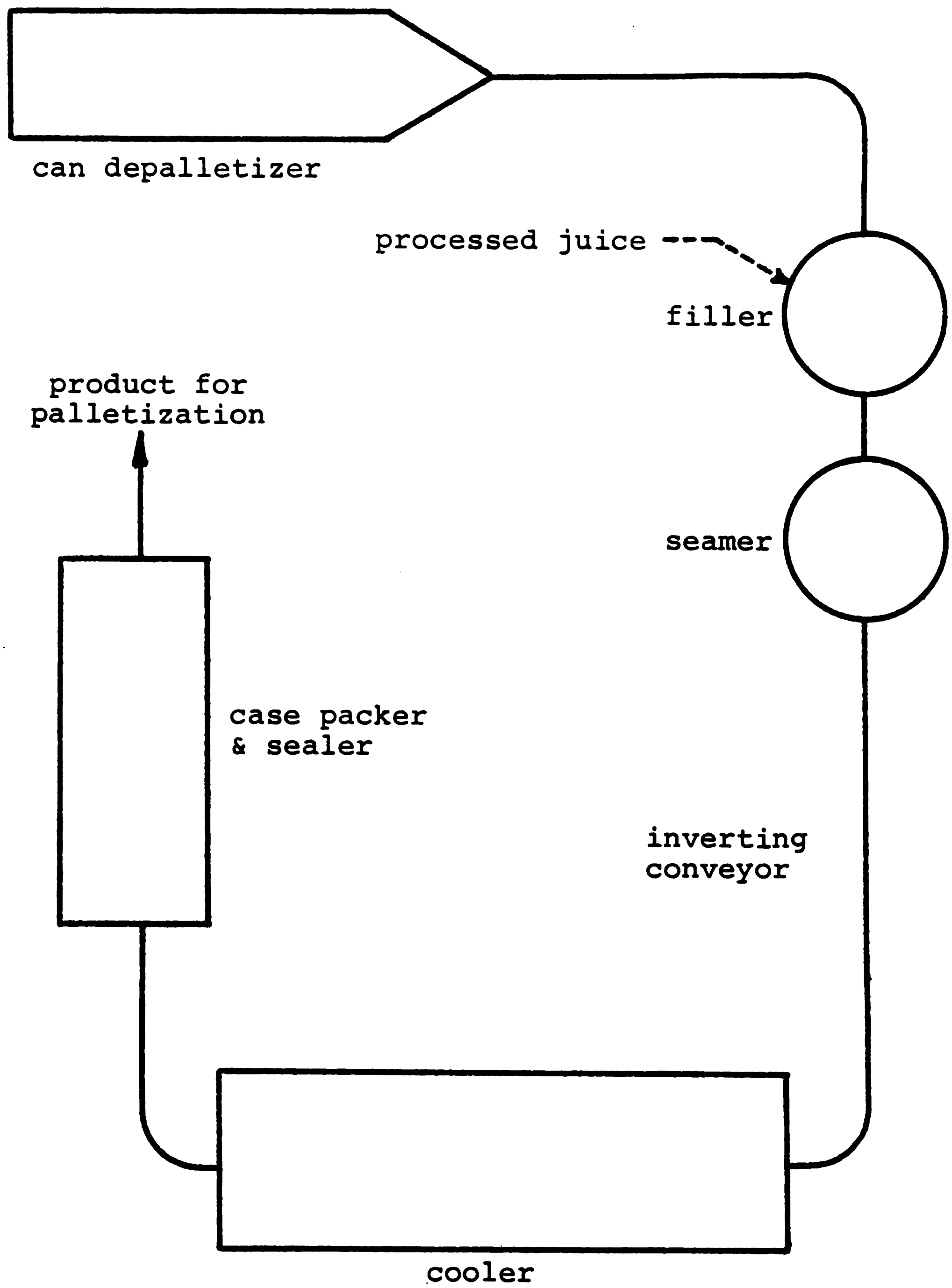

Figure A2. Canning line layout

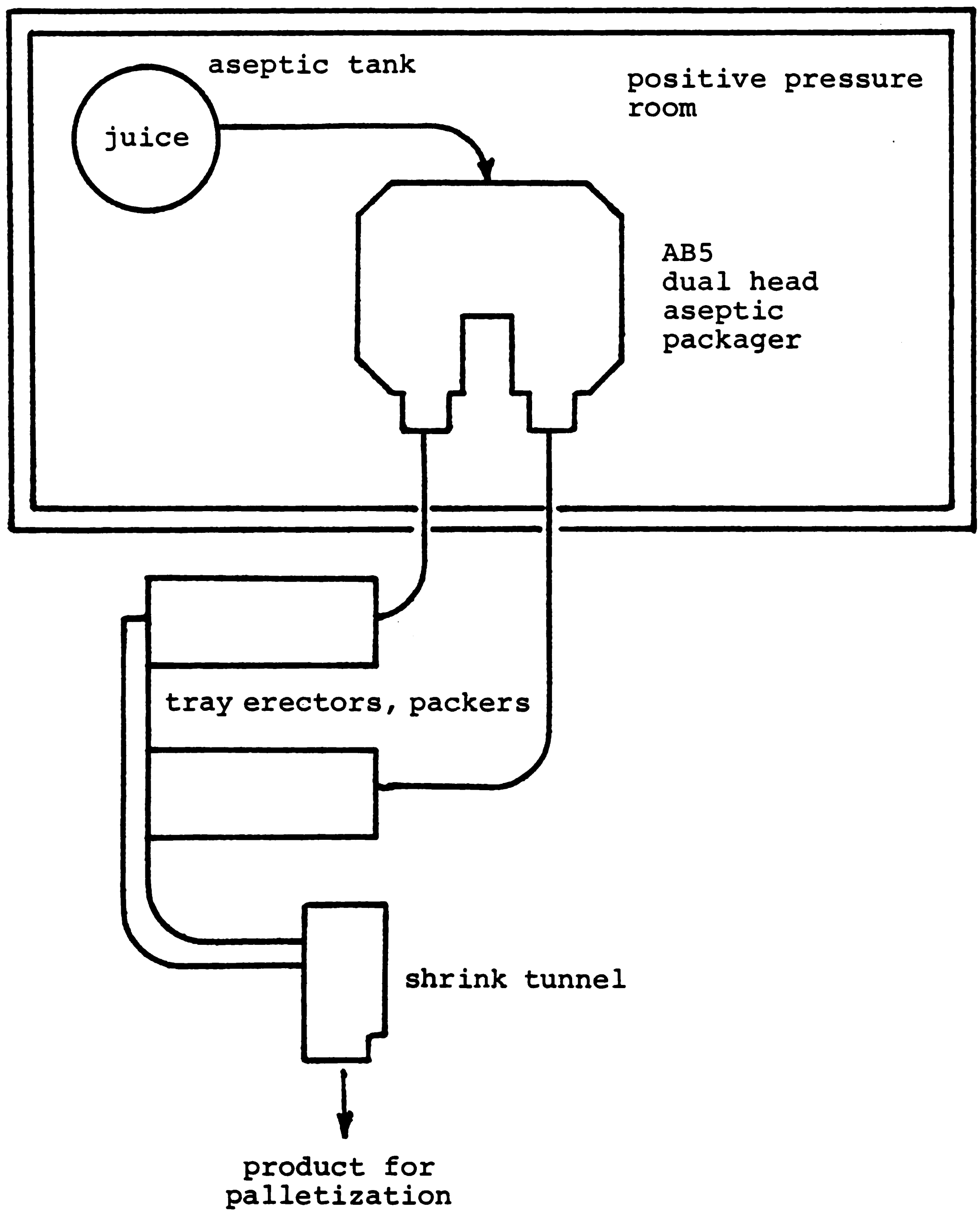

Figure A3. Tetra Brik line layout

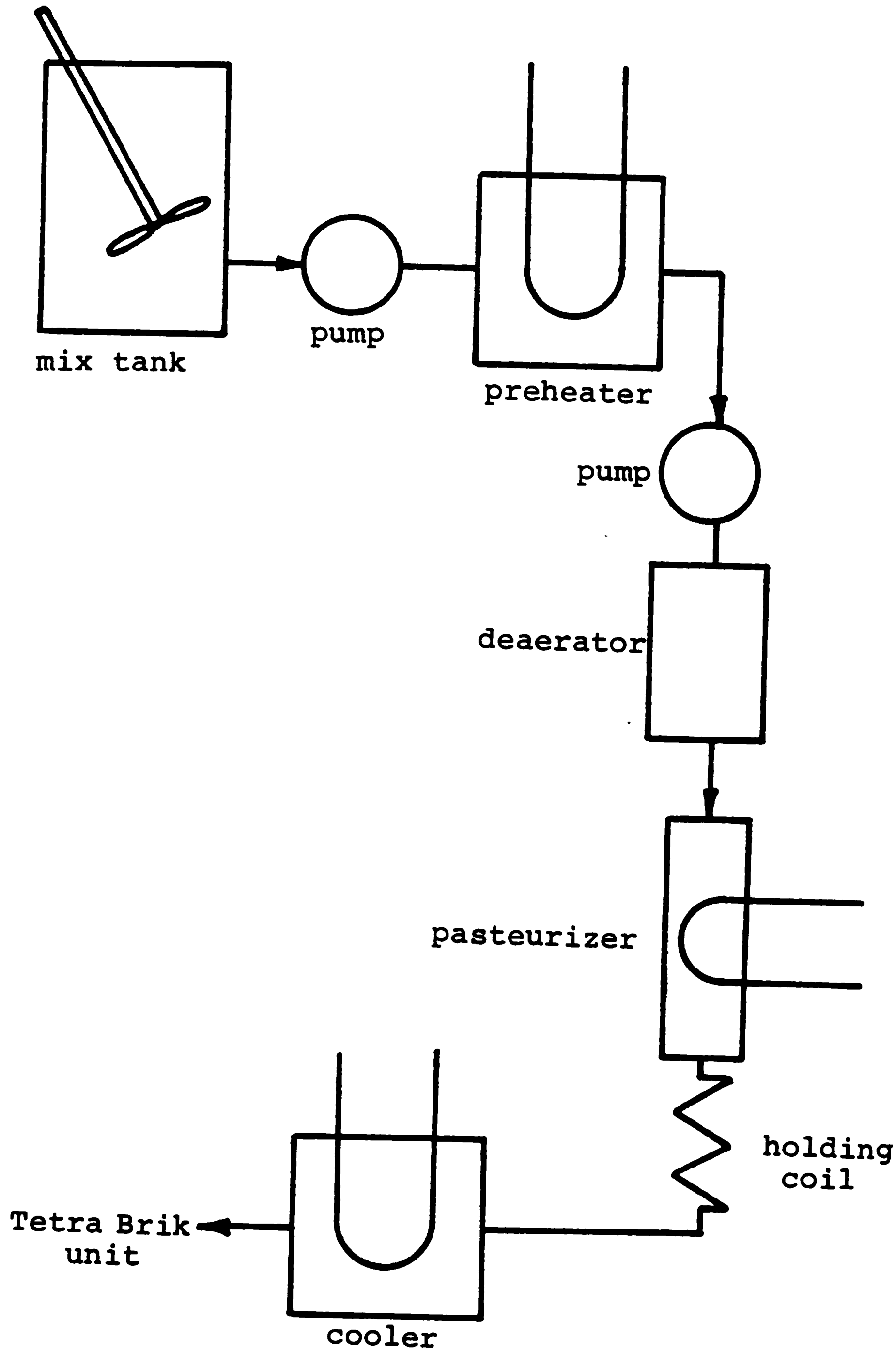

Figure A4. Tetra Brik test pack process flow

Name__________________ Date______________ Sample No.______

Please open this package, pouring the juice into the furnished glass. Rate how EASILY this was accomplished on the scale below:

Extremely difficult						Extremely easy
☐	☐	☐	☐	☐	☐	☐

Which sample would you prefer to use? (check one)

☐ Prefer first sample

☐ Prefer second sample

Do you have any comments?

Figure A5. Questionnaire for consumer evaluation of Tetra Brik opening and pouring utility

Name______________________ Date_____________ Sample No._____

Please taste the juice which matches the sample number above, comparing it to the juice marked "reference".

Assign an overall hedonic score (reference = 20) by circling the appropriate number below:

2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Figure A6. Questionnaire for Sensory Preference Test

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REFERENCES

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