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thesis entitled

THE CONCENTRATION AND DEACIDIFICATION OF RECLAIMED CONDENSATE FROM PROCESSED PEACHES (*Prunus persica* L.Batsch) USING ULTRAFILTRATION

presented by

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has been accepted towards fulfillment
of the requirements for

M.S. degree in Food Science

Major professor

Date Dec 10 1997

THE CONCENTRATION AND DEACIDIFICATION OF RECLAIMED CONDENSATE FROM PROCESSED PEACHES (Prunus persica L. Batsch) USING ULTRAFILTRATION

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Food Science

1997

ABSTRACT

THE CONCENTRATION AND DEACIDIFICATION OF RECLAIMED CONDENSATE FROM PROCESSED PEACHES (Prunus persica L. Batsch) USING ULTRAFILTRATION

By

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Peach condensate produced from a commercial process to concentrate peach soluble solids has been considered to be a waste effluent. This study demonstrated that the condensate can be used as a resource to increase the value of the final product. The puree and condensate fractions were generated from two peach cultivars classified as a low acid peach (A-142) and a high acid peach (A-9), respectively. The fresh processed purees and condensate fractions were compared using analytical techniques. The condensates were concentrated using an ultrafiltration membrane system to remove water and partition soluble constituents. The concentrated fractions were subsequently added back to the puree to form a sugar and flavor enhanced product. The condensates processed through the ultrafiltration system contained an increased concentration of sugars, polyphenolics, and volatile compounds compared to the original single strength condensate. Concentrated condensate was added back to the puree at varying amounts to make a final puree blend. The final puree of both cultivars had an increase in soluble solids, total acidity, and brix/acid ratio. The lightness and yellowness of the product decreased as the amount of condensate added back increased.

To My Parents

ACKNOWLEDGMENTS

I would like to extend my appreciation to my committee members Dr. Bennink and Dr. Dilley for their guidance through my graduate program.

I wish to extend a special appreciation to my major professor, Dr. Uebersax, for being a valuable resource and knowledgeable teacher. His patience and enthusiasm provided an enjoyable and stimulating atmosphere for growth during my graduate program.

I wish to acknowledge the Gerber Products Company, Fremont, Michigan for partial support of this project. Specifically, I wish to thank Mr. James Breinling for his interest and overall assistance. Further Dr. Emenhiser, S. LaVigne, and L. Kline for assistance with analytical procedures.

I would like to thank the Food Science graduate students at Michigan State University whose participation played a key role in my program.

A special appreciation is extended to my parents; their love, support, and encouragement were important to me during my education. A special thank you is extended to my best friend Stephanie. Her love and encouragement have been a constant source of strength throughout my program.

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INTRODUCTION

Processing of peach puree produces an abundant amount of condensate generated from direct infusion steam cooking. The condensate is composed of varying amounts of sugar, acid, volatile compounds, and water dependent on the raw peach condition and the processing procedure employed. These components vary extensively based upon cultivar, harvest maturity, and ripeness of the fruit. The condensate generated from the puree process is currently considered a waste effluent which reduces puree yield and is a costly biological oxygen demand (BOD) load. The condensate could be reclaimed by concentrating solids through an ultrafiltration system and then by adding them back to the final puree to enhance the flavor. The concentrated condensate would be high in sugars and flavor compounds and low in total acidity. This concentrated condensate could then be used to enhance the flavor of an immature peach used for puree and thus have significant financial advantage through improvement of raw product procurement options.

Rationale: The use of ultrafiltration technology to concentrate and deacidify reclaimed condensate could greatly increase the value of the final product. The final product would be sweeter, thus producing a more desirable product for the consumers. It would increase

the raw product procurement flexibility and reduce the amount of waste effluent produced at the commercial processing plant.

Null Hypothesis: The condensate generated from steam cooking peaches does not posses any value and should be discarded as a waste effluent.

LITERATURE REVIEW

PEACH FRUIT ORIGIN

The peach, Prunus persica, originated in China, near the city of Xian. Chinese records show that the peach was cultivated 3,000 years ago (Childers and Sherman, 1988) Today, peaches are widely distributed in temperate regions of North America and Europe. The leading peach producing countries in the world are the United States, Italy, France, Japan and Argentina. The leading peach producing states in the United States are Michigan, California, Georgia, Pennsylvania, New Jersey, North Carolina, and South Carolina (Ryall and Pentzer, 1974). Michigan produced 60 million pounds of peaches in 1995 and 40 million pounds in 1996 (Michigan Agricultural Statistics, 1996-97).

"Allgold" originated from a cross of NJ 55 4367 x G-17-5E made by Drs. L.F. Hough and Catherine Bailey of New Jersey Agricultural Experiment Station. Seeds were germinated and planted at the Fruit Substation, Clarksville, AR in 1966: the selection was made in 1971 and tested as A -142 (Moore et al., 1984).

CULTIVATION, HARVEST, AND POST HARVEST HANDLING

Soil conditions. Peach trees prefer a loam soil. Peach trees grow best in a soil having a pH ranging from 6.0 - 6.5. The soil needs to have proper water drainage to insure the roots will have sufficient aeration to function and live. Any areas of the field that are poorly drained will not support the life of a peach tree. The water table should be 3 feet from the surface when the tree starts to bloom (Patterson et al., 1993).

Climate conditions. Peach trees are grown in lower temperate latitudes which have hot summer climates and moderate winter temperatures. The peach tree is less winter hardy than the apple and pear trees. They thrive in areas which are free of early spring frosts. In general, peach varieties have modest chilling requirements, from about 400 - 800 hours. Peach trees will produce a high quality fruit in hot, arid regions where diseases like peachleaf curl and brown rot are easily controlled (Westwood, 1978). The counties located in the southwest region of Michigan are well suited for peach production due to the moderating temperatures caused by the "lake effect" during spring flowering.

Peach harvest. The maturity of the peach at harvest is important in obtaining a good quality peach for the fresh market or for commercial processing. Therefore, maturity indices have been developed and used to determine the optimum time of harvest.

Maturity indices used for peach include size, soluble solids, color, total acidity, and flesh firmness. During the maturation of peaches the flesh softens, the composition changes, a characteristic flavor develops, the green color of the skin decreases, the yellow or orange color of yellow-fleshed varieties increases and becomes more evident (Rood, 1957). Rood studied five varieties of peaches over a three year period to determine the optimum maturity for harvesting peaches and to obtain information necessary for

inspection and regulatory agencies. Maturity indices measurements included color, soluble solids, titratable acidity, chlorophyll content and use of Magness - Taylor flesh firmness tester with an 8 mm diameter plunger. Measurements at harvest ranked in the following order of usefulness in estimating the edible quality of peaches when ripe: pressure-test readings made on both pared cheeks, skin ground color, flesh color, chlorophyll content of the flesh, titrable acidity of the juice, and the percentage of soluble solids in the juice (Rood, 1957).

Delwiche and Baumgardner (1985) studied the peach ground color over the periods of growth, maturation and ripening for and early, mid-season, and late maturing cultivar. They found high correlations between color reference selection and measured Hunter "a" value, which demonstrated the feasibility of a ground color reference maturity index.

Forbus and Dull (1990) studied three cultivars of peaches to determine if delayed light emission would be a good indicator of peach maturity. They studied the relationship between delayed light emission and the physical and chemical properties that are related to the maturity of peaches. They concluded that delayed light emission could provide an effective, rapid, nondestructive technique for measuring peach maturity. Since high variability for fruit constituents exists, it is essential to define the compositional characteristics of fruit used for research studies.

PEACH FRUIT COMPOSITION

Sugar content. The major sugar found in ripe peach is sucrose (1.10 - 3.67 %), followed by glucose (0.71 - 2.25 %), fructose (0.62 - 2.59 %), and a small amount of the sugar alcohol sorbitol (0.24 - 1.50 %) (Robertson et al., 1988; Brooks et al., 1993). Brooks et al. (1993) reported that the stage of fruit maturity from green to ripe is not a critical concern in analyzing percentage of soluble solids, glucose, fructose, or total sugar content. However, it was important in evaluation of sucrose content, acidity, and sugar:acid ratio, which are all important flavor components. It was also shown that sucrose content and total sugars were not as likely to change from year to year as soluble solids, glucose, fructose, acidity, sorbitol, and sugar:acid ratio.

Selli and Sansavini (1995) showed that the fruit quality expressed as sugar-to-acid ratio in the last three weeks of fruit development grows greater daily. Thus, the choice of harvest date is extremely important on the type of quality and taste desired.

Meredith et al. (1989) stored peaches at 21 °C and 85 % relative humidity for a period of seven days. Peaches that were less than maturity chip 3 did not ripen, but remained green and firm. Peaches that were greater than maturity chip 3 did ripen and resulted in a decrease in acid concentration and an increase in sucrose and volatile components related to flavor, and the ground color went from green to yellow with the development of a red blush. As the fruit ripened over time, the sensory panels preference for the fruit increased.

Robertson et al. (1988) found that "high quality peaches" contained higher amounts of fructose and lower percentages of glucose and sorbitol than "low quality peaches." The overall flavor of the low quality cultivars was described as bitter and

astringent with a strong aftertaste. This flavor could be due to the high polyphenolic content of the low-quality peach.

Organic acid content. The major organic acids present in ripe peaches include malic, citric, and quinic. Small quantities of succinic have also been reported. The amount of acid present in peaches is dependent upon the stage of maturity at the time of harvest. The amount of acid present in peaches is also dependent upon the cultivar of peach. At full maturity, 'Babygold 5' and 'Babygold 7' had about 60 % malic, 20 % citric, and 19 % quinic, whereas 'Cresthaven' had 37 % malic, 35 % citric, and 28 % quinic. During ripening, both cultivars of 'Babygold' increased in malic acid and decreased in citric and quinic acids. The 'Cresthaven' cultivar did not show any significant changes among organic acids. However, the total levels of acid in all three cultivars decreased over the ripening process. Differences associated between 'Babygold' and 'Cresthaven' may be attributed to differences in genetic background (Wang et al., 1993).

Meredith et al. (1989) studied 'Harvester' peaches and found that ripening of maturity chip 1-3 did not ripen, and therefore had no significant effect on organic acid content. However, ripening of maturity chip 4-6 did ripen and the total organic acid content decreased. The concentration of malic acid increased and the concentration of citric acid decreased. The concentration of succinic acid remained the same throughout the ripening process.

Polyphenolic content. Peaches contain a number of phenolic compounds which generally impact bitter astringent taste characteristics on all fruits. The major phenolic compounds present in canned clingstone peaches included: four chlorogenic isomers, five

leucoanthocyanidin isomers, catechin, epicatechin, isoflavone, two p-coumarylquinic acids, and caffeic acid. Chlorogenic acids, leucoanthocyanidins, and catechin were present in the largest quantities (Luh et al., 1967).

Senter and Callahan (1990) identified chlorogenic acid, neochlorogenic acid, isochlorogenic acid, catechin, and epicatechin as the major monomeric phenols present in all peach cultivars studied.

Robertson et al. (1989) compared two cultivars of low quality peaches to two cultivars of high quality peaches. The low quality peach had seven times greater concentration of total phenols than the high quality peach. The taste of the low quality peach was described as bitter and astringent with a strong aftertaste. They concluded that the undesirable flavor was associated with the high polyphenolic content of the low quality peach.

Volatile compound content. Volatile compounds identified in Red Globe freestone peaches included: acetaldehyde, methyl acetate, ethyl acetate, ethyl alcohol, hexyl formate, hexyl acetate, trans-2-hexenyl acetate, hexyl alcohol, acetic acid, trans-2-hexene-1-ol, benzaldehyde, isovaleric acid, ethyl benzoate, gamma-caprolactone, benzly acetate, gamma-heptalactone, caproic acid, benzyl alcohol, gamma-octalactone, gamma-nonalactone, hexyl benzoate, gamma decalactone, alpha-pyrone, and delta-decalactone. Jennings and Sevenants (1964) and Sevenants and Jennings (1966) concluded that the typical peach aroma is not due to one or two compounds, but it is made of a wide spectrum of compounds whose individual aromas are not at all peach-like.

Spencer et al. (1978) quantified volatile compounds in ten varieties of peaches. They concluded, linalool, alpha-terpineol, cis-3-hexenyl acetate, furfural, gamma-

dacalactone, geraniol, and an unidentified monoterpene to be the most abundant compounds present in most varieties.

Horvat et al. (1990) identified thirty-three compounds which included: five C_6 aldehydes and alcohols, six lactones, five monoterpenes, one sesquiterpene, one ester, three high molecular weight hydrocarbons (C_{21}, C_{23}, C_{25}), and twelve other compounds. Major compounds identified included: hexanal, (E)-2-hexenal, benzaldehyde, linalool, 6-pentyl-α-pyrone, γ- and δ-decalactones, hexadecanoic acid, and three saturated hydrocarbons. As the maturity of the fruit increased, the concentrations of most compounds increased.

Horvat and Chapman (1990) found C_6 aldehydes as the major compound in immature peaches. The concentration of C_6 aldehydes decreased as the maturity increased. A significant increase in benzaldehyde, linalool, and γ- and δ-decalactones occurred in peaches which reached maturation of 134-143 days after flowering.

MEMBRANE PROCESSING THEORY

Descriptive terminology. The membrane separation process is illustrated in figure 1. The feed solution enters the membrane system and an external driving force (e.g. pressure differential (positive or negative), concentration gradient, or applied electrical potential) is applied to the solution to allow passage of certain molecules to flow through the membrane. The molecules that flow through the membrane are called the permeate. The molecules that do not pass through the membrane are called the retentate or concentrate (NFPA, 1993). The primary role of the membrane is to act as a selective barrier. It should retain certain components of the feed solution and permit other

components to flow through (Cheryan, 1986). Various intrinsic factors influence membrane performance including viscosity and osmotic pressure.

The flux is the rate at which permeate passes through the membrane. Flux rate is expressed as the volume of permeate per unit time per unit membrane area. Flux rate units are usually expressed as follows: gallon/ ft^2 /day (gfd) or liter/ m^2/ hr (lmh). Mathematically, flux rate is expressed as follows:

$J = A \times (Pf - Pp)/ u$

-Where J equals the flux rate

-Where A equals the membrane permeability coefficient

-Where P equals the transmembrane pressure

-Where f equals the feed stream

-Where p equals the permeate stream

-Where u equals the fluid viscosity

The rejection or retention coefficient measures the membrane's ability to separate or retain solution components. It is the fraction of the component (or a group of components) that are retained by the membrane and is usually expressed as a percentage of the original component concentration in the feed stock.

$Rejection = 100 \times ((Fi - Pi)/Fi)$

-Where i equals a specific component or group of components

-Where F equals the concentration of i in the feed stream

-Where P equals the concentration of i in the permeate stream

Recovery is the fraction of the feed that is recovered as permeate (Mohr et al. 1989; NFPA 1993).

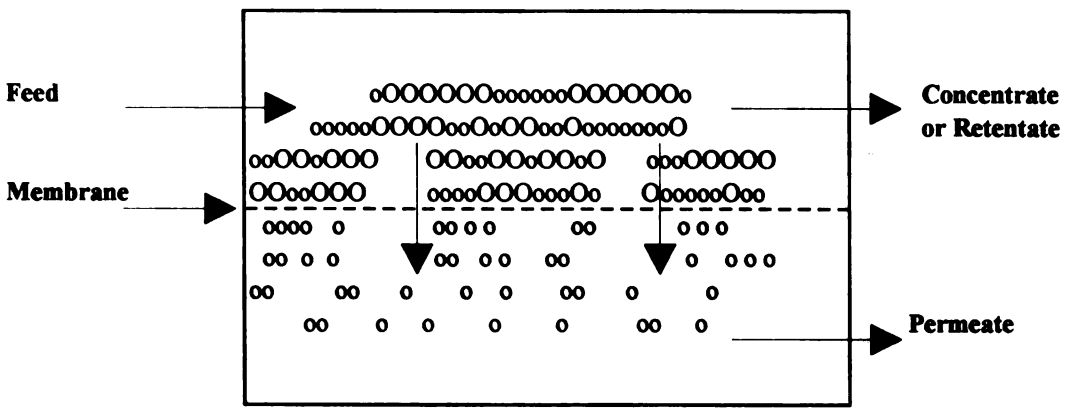


Figure 1 Schematic diagram illustrating the process of membrane separation based on size

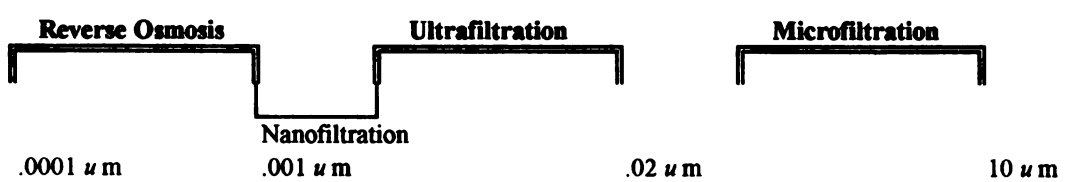


Figure 2 Classification of membrane systems based on priority size

Intrinsic factors. Fluid characteristics are measured by the Reynold's Number, which is the ratio of inertial forces to the viscous forces (Singh and Heldman, 1984).

N_{Re} = inertial forces = pDV/ u where:

viscous forces

p = density

V = mean velocity

D = diameter

u = viscosity

-Re< 2300 would be laminar

-2300< Re< 10,000 would be transitional flow

-Re> 10,000 would be turbulent flow

Turbulent flow is preferred over laminar flow because heat transfer is much greater at the geometric center due to the random molecular action. Food products which are viscous (concentrated sugar solutions) tend to exhibit laminar flow. Food products which are not viscous (juices) tend to exhibit turbulent flow (Harper, 1979). Usually, turbulent flow will increase the flux (Cheryan, 1986).

The osmotic pressure differential increases the driving force related to the temperature and the molar concentration of the solution. The osmotic pressure can be calculated by using van't Hoff's equation (Hwang and Kammermeyer, 1975).

Osmotic pressure = RTC

-Where R = universal gas constant

-T = absolute temperature (degrees Kelvin)

-C = molar concentration of the solute

The osmotic pressure increases as the concentration of solute increases. This increase in osmotic pressure will require higher operating pressures to overcome the osmotic pressures of the solutes being separated.

CLASSIFICATION OF MEMBRANE PROCESSING SYSTEMS

Microfiltration. The classification of membrane systems is illustrated in figure 2. Microfiltration is a technique used for removing large macro-molecules and suspended solids in the size range of 0.02-2.0 microns. This separation process allows suspended solids to be retained in the concentrate and allow a clear liquid to pass through the membrane. In general, microfiltration is used as a purification procedure in which the permeate stream is used as a product. However, there are applications for the concentrated suspended solids (Mohr et al., 1989).

Ultrafiltration. Ultrafiltration is used to remove particles in the size range of 0.001-0.02 microns. The molecular weight cut off is about 300- 500,000 daltons depending upon the membrane structure. Ultrafiltration deals with the separation of molecules like proteins, starches, gums, and colloidally dispersed compounds such as clays, paints, pigments, latex particles (Cheryan, 1986).

Nanofiltration. Nanofiltration is a separation process which was developed in the 1980's. The separation capabilities of the nanofiltration membrane lies between the ultrafiltration and reverse osmosis systems. The molecular weight cut-off is around 300 - 1000 daltons. Nanofiltration is used in the separation of ions from solutes such as small molecules of sugars. Operating pressures of nanofiltration systems are typically lower than reverse osmosis systems, but yield higher flow rates of water.

Nanofiltration systems are used when divalent cation salts such as magnesium and calcium need to be removed, but high sodium rejection, typical of reverse osmosis, is not needed. The nanofiltration membrane has a low rejection of monovalent ions and a high rejection of divalent ions. Typical rejections are 60% for NaCl, 80% for calcium bicarbonate and 98% for magnesium sulfate, glucose and sucrose (Scott and Hughes 1996).

Reverse Osmosis. Reverse osmosis (RO) uses an applied pressure which is greater than the normal osmotic pressure of water, to reverse the flow across a semipermeable membrane. If the applied pressure is less than the osmotic pressure, the water will flow from a dilute solution to a concentrated solution. This phenoma is referred to as osmosis. If the applied pressure is equal to the osmotic pressure, the water will not flow and the system will be at osmotic equilibrium. If the applied pressure is greater than the osmotic pressure, the water will flow from a concentrated solution to a dilute solution. This phenoma is referred to as reverse osmosis (Lonsdale, 1982). Reverse osmosis or hyperfiltration has a molecular weight cutoff of 300 - 500 daltons and rejects solutes having a molecular size of 0.1 to 1.0 nanometer (Mohr et al., 1989). Thus, RO has extensive application in water purification systems.

MEMBRANE MODULE AND SYSTEM STRUCTURES

There are four distinct membrane modules available today. These include: Plate and frame, spiral wound, tubular, and hollow fiber. Each of these have individual advantages and disadvantages, with distinct selection criteria used for specific products.

Plate and Frame. The plate and frame module or flat plate module was among the first membrane modules ever made. The concept of this design originated from the conventional filter press. The plate and frame module consists of flat sheets of membranes, spacers, membrane plates and end plates. The membranes are bonded to inert membrane plates, which provide little resistance to flow. These are then sandwiched between spacers to act as flow channels. The membranes, membrane plates, and spacers are packed tightly together between endplates. A high packing density can be achieved by sandwiching a number of membranes together. The feed flow and retentate flow in one set of channels, while permeate flows in alternate channels (Strathmann, 1981; Mohr et al. 1989).

The major advantages of using the plate and frame module are: 1) permeate can be examined separately from each membrane, 2) minimum floor space is required, 3) good performance with viscous solutions and easy replacement of membranes.

Two major disadvantages to the plate and frame system are the susceptibility to plugging (membrane fouling) resulting in decreased flux rate performance and difficulty to clean and sanitize (Belfort, 1988; Renner and Abd El-Salam, 1991).

Spiral Wound. The spiral wound membrane resembles the plate and frame membrane, except the membrane is rolled in a cylinder on a central axis. The membrane, feed flow channel, and membrane support are wrapped around a cylindrical porous tube. The entire membrane is then wrapped by an outer shell, which can be made of various materials. The feed flow and retentate flows axially along the membrane and into the channels formed by wrapping. The permeate flows spirally to the porous tube in the

center of the membrane. Thus, allowing the permeate to flow out of the system (Mohr et al., 1989).

The major advantages to using the spiral wound membrane are: high surface area per unit volume, which will decrease floor space, minimum energy consumption, and low capital and operation costs.

The major disadvantages to the spiral wound membrane are: fouling problems when using a feed solution which is high in suspended solids, high pressure drop across the membrane when using a very viscous feed stock, difficult to clean, and the entire membrane element must be replaced if found to be faulty (Renner and Abd El-Salam, 1991).

Tubular module. The tubular module is relatively simple compared to the other membrane types. They are constructed by forming the membrane around the outside of a porous tube or by forming the membrane on the inside of the tube. The feed solution can enter the module on either the tube side or shell side, depending upon the location of the membrane. For example, the pressurized feed solution flows down the tube and the solution is allowed to permeate through the membrane, which is then collected on the shell side. The tubes can range in diameter of 1 to 2.5 cm. and are usually packed in series or as parallel array (Strathmann, 1981; Mohr et al., 1989).

The major advantages of the tubular module are: easy replacement of membrane tubes, capable of handling feed streams with large suspended particles, and cleaning of membranes is easy.

The major disadvantages of the tubular model are: need efficient pumps to generate high velocity, low surface area to volume ratio, high energy consumption, high

pressure drop, and large amount of floor space required to run the system (Renner and Abd El-Salam, 1991).

Hollow-fiber module. The hollow-fiber module is constructed of bundles of fiber elements, which are orientated in parallel and placed inside a cartridge. All of the fibers are embedded in a resin at their ends and enclosed in a permeate collecting tube. The feed solution flows through the fibers and the permeate is collected outside. The hollow fiber elements are self-supporting capillary tubes, which range in diameter from 50 to 100μm (Strathmann, 1981; Renner and Abd El-Salam, 1991).

The major advantages of the hollow-fiber module are: high surface area volume, low energy consumption, fairly resistant to blockage of the flow channel and improved cleanabilty by back flushing.

The major disadvantages of the hollow-fiber module are: can be easily damaged during use, low maximum pressure allowed, isolation of damaged element is difficult without shutting down, and damage to single fiber requires replacement of the entire cartridge.

MEMBRANE FOULING

Characterization of fouling. A major limiting factor in pressure driven membrane processes is the reduction of flux to below the theoretical capacity of the membrane. The decrease in flux over time is termed as "fouling" of the membrane. Fouling manifests itself as a decline in flux over a period of processing time (Cheryan, 1986; Scott and Hughes, 1996).

The decline in flux can be subdivided into three phases: 1) a sharp decrease of flux in the first few minutes, 2) followed by a long period of time at a nearly constant flux, and 3) a decline in flux that approaches zero. The declining flux is due to the exponential increase in suspension viscosity, which has clogged the membrane pores (Riesmeier et al., 1987).

The major modes of fouling include: adsorption, precipitation, pore blocking, particulate adhesion, chemical reaction, electrical attraction, and other interactions. The rate of fouling is influenced by nature of the foulants. Foulants can include dissolved organic matter (proteins, carbohydrates, oils) microorganisms, soluble inorganic compounds (carbonates, sulfates, silica), colloidal or particulate matter (suspended solids, metal oxides). Proper cleaning of the membrane can usually eliminate foulants of this type. Thus, restoring the membrane back to its original condition (Scott and Hughes, 1996; NFPA, 1993).

Another type of fouling that can occur is due to the change in the actual structure of the membrane. A decrease in permeability of the membrane is sometimes due to a permanent physical change in the polymeric membrane, referred to as compaction or creep. Compaction is a physical phenomenon in which the membrane increases in density during operation due to the effects of pressure and temperature. This type of fouling is not reversible, thus cleaning will not restore the membrane back to its original permeability (NFPA, 1993; Mohr et al., 1989).

Process factors affecting fouling. Factors which influence fouling include: physico-chemical interactions of the feed solution, temperature, flow rate, pressure and feed concentration (Cheryan, 1986).

Physico-chemical interactions are very common between solution species and membrane material. For example, macrosolutes such as proteins, can bind to polymer surfaces by a variety of mechanisms including: charge transfer (ex. hydrogen bonding), electrostatic interactions, hydrophobic effects, or through a combination of these (Fane and Fell, 1987).

The effect of temperature on membrane fouling is not very clear (Cheryan, 1986). According to the Hagen-Poiseuille model, increasing the temperature should increase the flux. An increase of 20°C in acid whey, clearly showed a significant increase in flux (Kuo and Cheryan, 1983). In milk and whey, an increase of 30-50°C will have a positive effect on reducing fouling (Renner and Abd El-Salam, 1991). However, there are some cases where the physico-chemical properties of the feed solution decrease in solubility with an increase in temperature. The overall effect is a decrease in flux at higher temperatures (Cheryan, 1986). In milk, overheating will decrease solubility of calcium phosphate and increase heat denaturation of whey proteins which will cause fouling (Renner and Abd El-Salam, 1991).

Pressure will increase the flux rate and decrease the fouling of the membrane in the pre-gel region. As the pressure increases, the gel layer (boundary layer) reaches a concentration limit where flux becomes independent of pressure (concentration polarization). If the pressure is increased beyond this point, only a temporary increase in flux will occur. Thus, the system will be essentially unchanged. Consequently, the gel layer has become thicker and denser which will reduce flux until it reaches its initial steady state. Compaction of the gel layer will occur if the pressure increases over a critical point, resulting in a lower flux rate (Cheryan, 1986; Renner and Abd El-Salam, 1991). At high

pressures, high flow rates increased rate of fouling in acid (cottage cheese) whey (Kuo and Cheryan, 1983).

The velocity of the feed is an important factor in membrane fouling. Generally, higher flow rates decrease membrane fouling by continuously removing particles which are deposited on the membrane surface. The high shear rates achieved by increased flow rates reduces the hydraulic resistance of the fouling layer (Cheryan, 1986; Renner and Abd El-Salam, 1991).

Acid (cottage cheese) whey was used to study the effects of fouling at different flow rates. The increased flow rate had a positive effect on decreasing fouling to a point. At low pressures (35-45 psi), the increased flow rate helped to combat the effects of fouling. However, at high pressure (70 psi) the increased flow rate did not decrease fouling, but could have actually increased fouling (Kuo and Cheryan, 1983).

ULTRAFILTRATION OF FRUIT JUICES

Ultrafiltration has been used commercially to enhance the economic value and quality of a wide variety of fruit juice products. Kirk et al. (1983) used hollow fiber membranes to obtain a clear, amber-colored pear juice. Three membrane sizes were used ranging from 50,000 to 10,000 dalton molecular weight cut-off. The flux of permeate changed with process temperature and transmembrane pressure. The optimum flux was achieved at 157 kPa with feed stream velocity of 0.15 m/s at 50 °C. There was a linear relationship between temperature and flux, but at the higher temperatures the membrane stability is limited and the quality of pear juice decreased. The flux decreased linearly with the logarithm of the concentration.

Hernandez et al. (1992) used three hollow fiber membranes to clarify grapefruit juice and grapefruit pulp wash as a preliminary process to remove bitter tasting compounds like limonin, naringin, and other flavonoids. The resulting permeate was a clear serum with no suspended solids. Flow rate of permeate increased with transmembrane pressure up to 137.8 kPa. Above that pressure, the membranes experienced the concentration polarization effect. The permeate was then run through a resin column which debittered the juice, resulting in a more desirable flavor.

Su et al. (1993) used cross-flow microfiltration to clarify commercially pressed depectinized apple juices and pectin containing artificial juice suspensions under low pressures with periodic gas backwash to remove solids attached to the membranes. Results showed that increases in pectin concentration decreased the flux. Also, continuos cross-flow microfiltration with periodic gas backwash was useful to improve flux and clarity of non-cloud apple juices at low linear feed velocities, low temperature, and relatively low transmembrane pressure.

Sheu and Wiley (1983) used plate and frame reverse osmosis to concentrate single strength apple juices. Two membranes types consisting of cellulose acetate and high resistant membranes were used. Both membranes concentrated the brix from 10° to 20-25° Brix and showed similar processing capabilities. The cellulose acetate membranes had a recovery of 78.4 % soluble solids and 16.9 % apple aroma. The high resistance membranes recovered 95 % soluble solids and 81 % apple aroma (Sheu and Wiley, 1983).

MATERIALS AND METHODS

PEACH ORIGIN

Two cultivars of peaches produced during the 1996 crop year were used in this study. The Arkansas - 9 peaches were grown at Lakeshore Orchard in Shelby, Michigan. Arkansas -9 peaches had a 17.4 °B and 23 brix/acid ratio. The Arkansas -142 peaches were grown at Lister Orchard in Ludington, Michigan. Arkansas -142 peaches had a 19.2 °B and 78 brix/acid ratio. Approximately 1500 lbs (680.4 kg) of peaches were transferred from the orchards in two large wooden totes (one tote for each designated cultivar) and loaded onto a pick up truck. The peaches were delivered to Michigan State University on September 11, 1996 and were processed at Michigan State University, Food Processing Center on September 12, 1996. Figure 3 illustrates the major components of the project beginning with raw peaches.

PEACH PREPARATION, CONDENSATE, AND PUREE PROCESS

Figure 4 illustrates the peach puree and condensate preparation process. Whole peaches were washed in a Sinclair - Scott Tumbler (serial # JVW 517 B) using cold water. Washed peaches were then peeled using 1 -2 % Lye at 190 °F for 3-4 minutes. Peaches were rinsed and loaded into a Rietz Thermascrew Steamer (model # TH-9-K2204). The

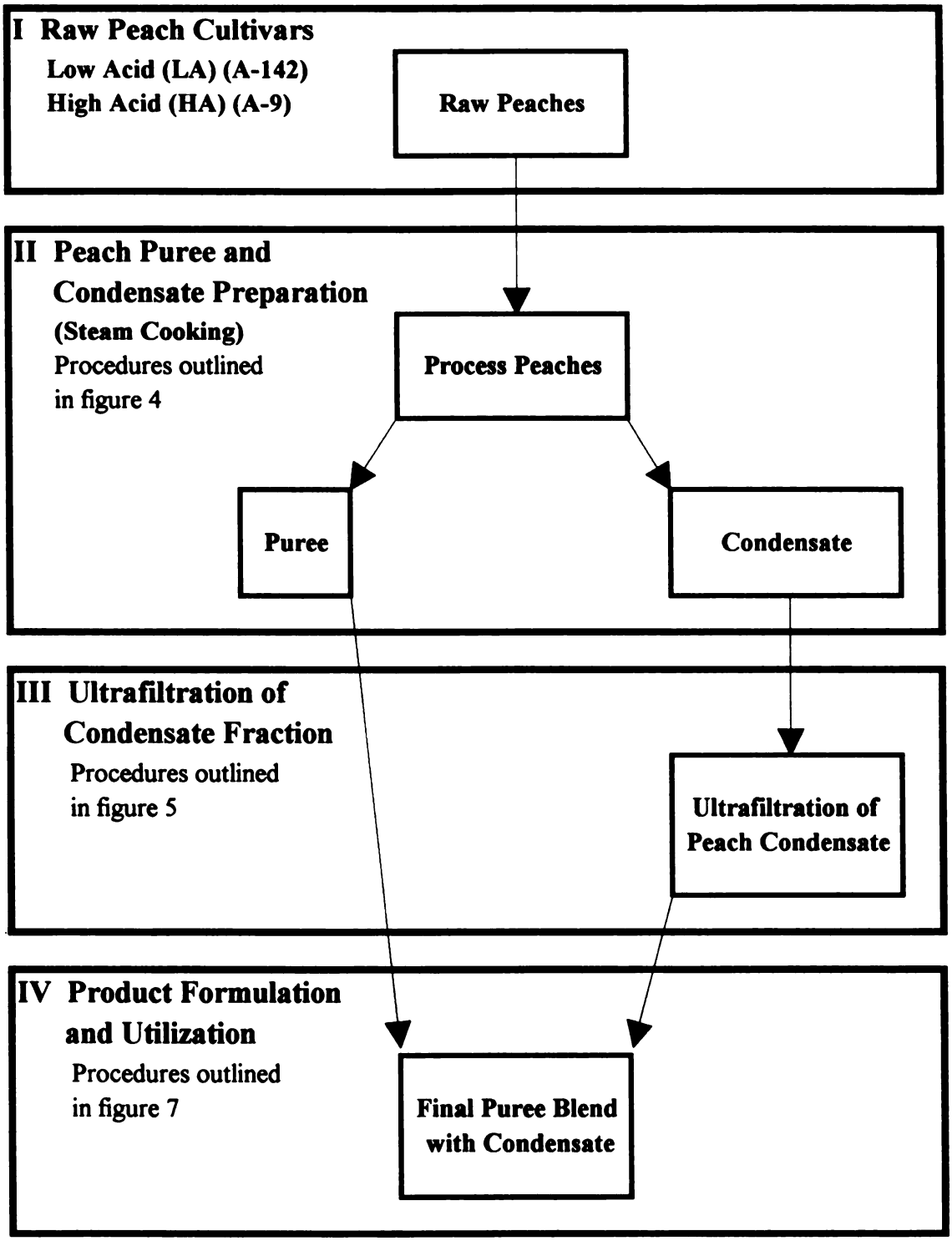


Figure 3 Flow chart of peach processing of two cultivars [low (A-142) and high (A-9) acid] illustrating the major components of the project: I Raw peach cultivars, II Peach puree and condensate preparation, III Ultrafiltration of condensate fraction, IV Product formulation and utilization

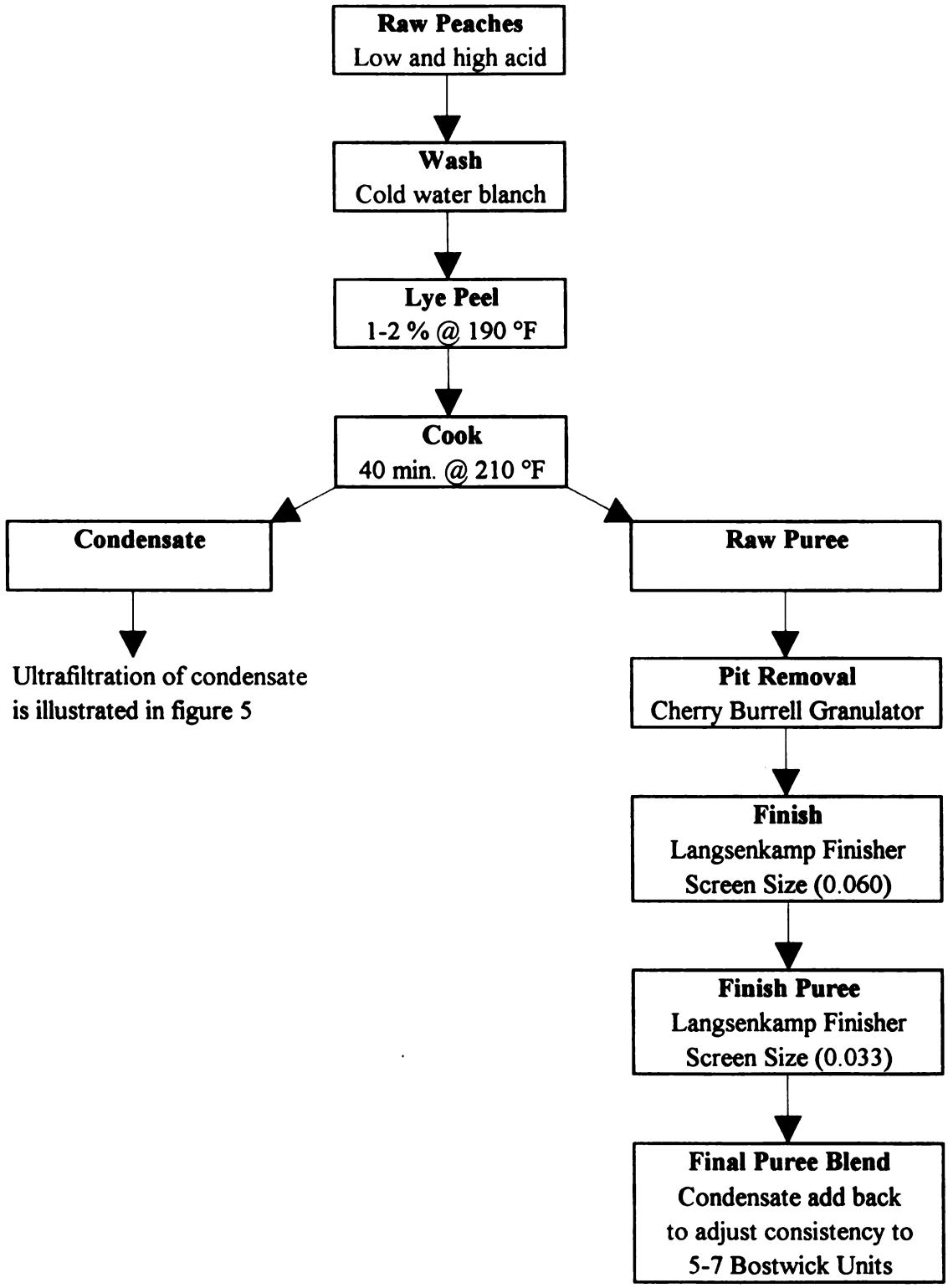


Figure 4 Flow chart of peach puree and condensate preparation (steam cooking) used on low (LA; A-142) and high (HA; A-9) acid peach cultivars

peaches were cooked at 212 °F for 40 minutes. The condensate was collected and allowed to cool. Once cooled, the condensate was placed in buckets lined with plastic bags. The condensate was transferred to a walk in freezer maintained at -5 °C for later use in the ultrafiltration system. The peaches were pitted using a Cherry Burrell Granulator (model # 542). The peaches were run through a Langsenkamp Finisher (model # 185 SC) with screen size of 0.060. Then the peaches were run through the same finisher with screen size of 0.033. The peach puree was allowed to cool and transferred to buckets lined with plastic bags. The peach puree was placed into the freezer until the concentrated condensate was added back to the puree.

ULTRAFILTRATION PROCESS SYSTEM

Pre-filter treatment. The peach condensate was thawed and filtered through a cheese cloth. The condensate was poured into a 30 gallon steam kettle and heated to 100 °F. A positive displacement pump (serial # 0056327SS) was used to transfer the condensate from the steam kettle to the APV Ultrafiltration System (WO # 27081) where it passed through a dairy filter (80 micron) and into a large feed stock vat. The ultrafiltration of condensate fractions is illustrated in figure 5. A schematic diagram of the ultrafiltration process system is illustrated in figure 6.

Microfiltration. The condensate was pumped from the feed stock vat and passed through a spiral wound membrane (Desal Model JX2540C1086). Membrane had a surface area of 15 ft^2. The operating pressure was 50 - 75 psi. The temperature of the

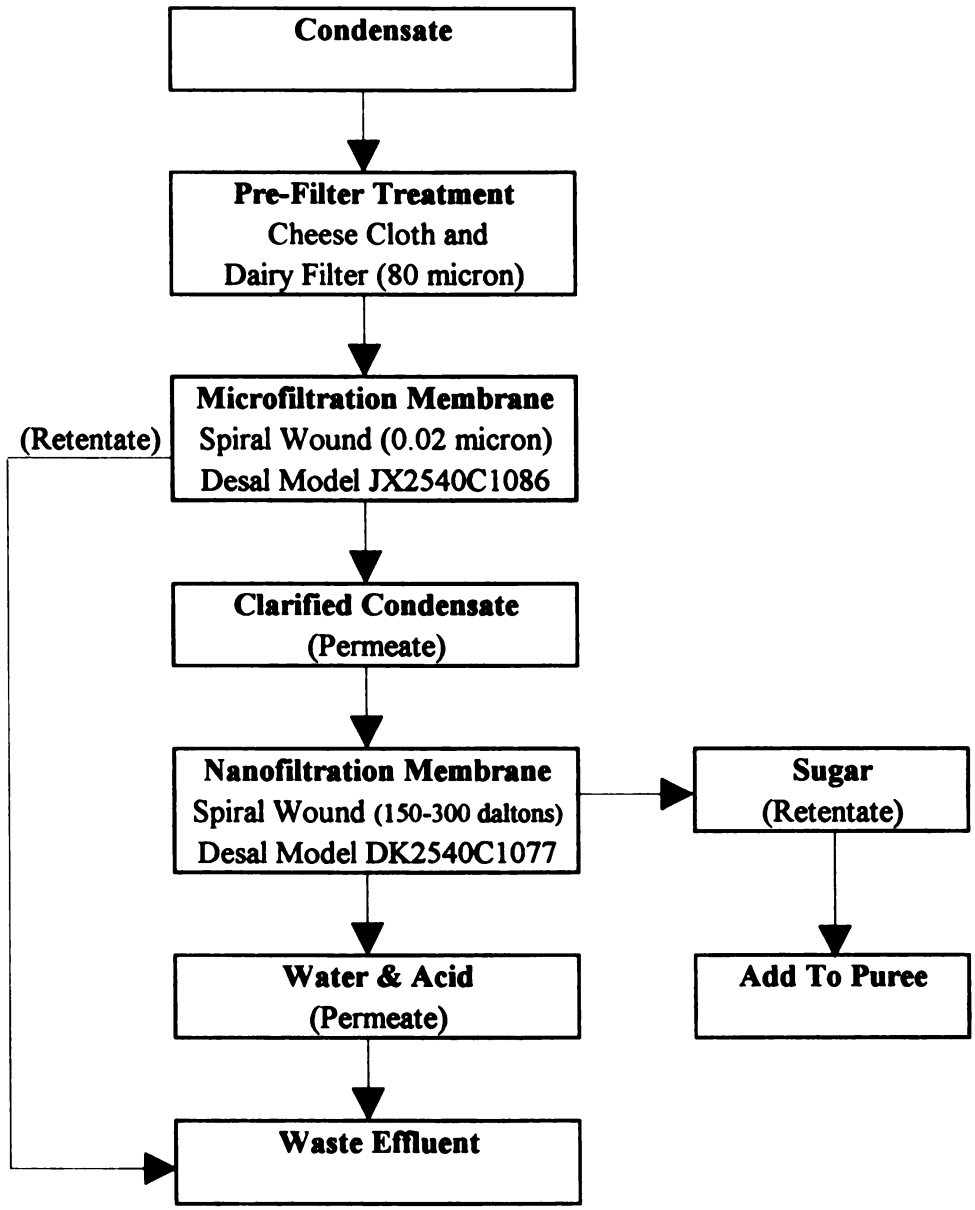
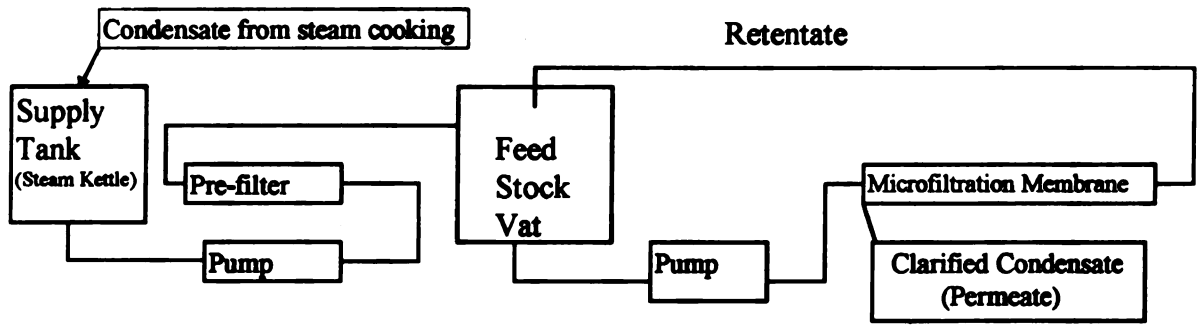


Figure 5 Flow chart of ultrafiltration of condensate fraction used on both commercial condensate and condensate generated from low (LA; A-142) and high (HA; A-9) acid peach cultivars

I. Pre-filter treatment and microfiltration of condensate from steam cooked peaches



II. Nanofiltration of clarified condensate generated from microfiltration

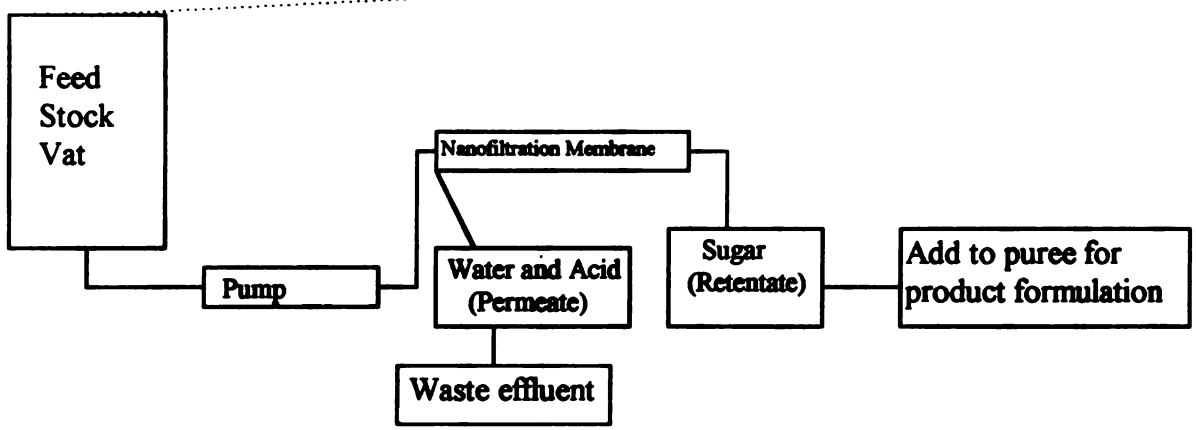


Figure 6 Schematic diagram of ultrafiltration process system illustrating pre-filter treatment, microfiltration, and nanofiltration

condensate was 99-102 °F. The permeate was collected and the retentate was recirculated continuously until the flow of permeate ceased.

Nanofiltration. The condensate was pumped from the feed stock vat and passed through a spiral wound membrane (Desal Model DK2540C1077). Membrane had a surface area of 19 ft^2. The operating pressure was 350 - 400 psi. The temperature of the condensate was 99-102 °F. The permeate and retentate were collected and weighed after each run. The retentate was manually poured back into a feed stock vat and the UF system was operated until the amount of retentate left was less than 25 pounds. All flow rates were measured with a graduated cylinder and stopwatch.

ANALYSIS OF SUGARS

High pressure liquid chromatography was utilized to quantitate sugar content of peach condensates and peach purees. Peach samples which had a high degree brix were diluted 1 : 5 with water. The samples which had a low degree brix were run at full strength. Due to the low volume of water in the high acid puree, the sample was diluted 1 : 2 with water and then separated in a centrifuge. Both the low acid and high acid purees were centrifuged in a Beckman J2-21 centrifuge at ten thousand rpm for 15 minutes. The supernatant was drawn off and all of the samples were filtered using a Gelman Nylon Acrodisc 0.45 μm filter placed on the end of a B-D 5 cc syringe. Approximately two mls of sample were placed in a small vial and capped with a PFTE Septum (Waters # 73005) cap.

Two sugar standards were prepared and run randomly throughout the samples. One sugar standard contained 1.49 % sucrose, 0.80 % glucose, 0.92 % fructose, and 0.52

% sorbitol. The second sugar standard contained 2.24 % sucrose to account for higher sucrose levels in the peach samples.

The high pressure liquid chromatography system used was composed of several separate modules integrated into the fluid flow. These modules included a Waters 712 Autosampler, Waters 600E Controller, Waters 610 pump, Waters 410 Differential Refractometer, Phenomenex Rezex Monosaccharide Column (300 x 7.8 mm serial # 147185), and Peak Pro computer software.

The autosampler injected 10 ul of sample into the system which ran for 25 minutes at a flow rate of 0.6 ml/min. Milli-Q water was used as the mobile phase and the column maintained a temperature of 85 °C.

ANALYSIS OF ORGANIC ACIDS

High pressure liquid chromatography was utilized to quantitate organic acid content of peach condensates and peach purees. Peach samples used for organic acid analyses were generally run at full strength. However, due to the low volume of water in the high acid puree, the sample was diluted 1 : 2 with water and then separated in a centrifuge. Both the low acid and high acid purees were centrifuged in a Beckman J2-21 centrifuge at ten thousand rpm for 15 minutes. The supernatant was drawn off and all of the samples were filtered using a Gelman Nylon Acrodisc 0.45 *u*m filter placed on the end of a B-D 5 cc syringe. Approximately two mls of sample were placed in a small vial and capped with a PFTE Septum (Waters # 73005) cap.

Two standards were prepared and run randomly throughout the samples. The first standard was a combination of 250 mg of quinic, 600 mg of malic, and 914 mg of

citric diluted with Milli-Q water into a 100 ml volumetric flask. The second standard was 50 ppm furmaric diluted with Milli-Q water into a 100 ml volumetric flask.

The high pressure liquid chromatography system used was composed of several separate modules integrated into the fluid flow. These modules included a Waters 712 Autosampler, Waters 600E Controller, Waters 610 pump, Waters 490 Programmable Multiwavelength Detector, Phenomenex Spherex 5 C18 Columns(50 x 4.6 mm and 250 x 4.6 mm serial # 179224), and Peak Pro computer software.

The autosampler injected 10 *u*l of sample into the system and ran for 1 hour at a flow rate of 0.5 ml/min. The mobile phase of the system was 10.0 g potassium phosphate monobasic per liter (pH 2.6) and the column was maintained at an ambient temperature.

ANALYSES OF POLYPHENOLICS

High pressure liquid chromatography. Polyphenolic samples were generally run at full strength. However, due to the low volume of water in the high acid puree the sample was diluted 1 : 2 with water and then separated in a centrifuge. Both the low acid and high acid purees were centrifuged in a Beckman J2-21 centrifuge at ten thousand rpm for 15 minutes. The supernatant was drawn off and all of the samples were filtered using a Gelman Nylon Acrodisc 0.45 *u*m filter placed on the end of a B-D 5 cc syringe. Approximately two mls of sample was placed in a small vial and capped with a PFTE Septum (Waters # 73005) cap.

The high pressure liquid chromatography system used was composed of several separate modules integrated into the fluid flow. These modules included a Waters 710 B Autosampler, Waters 600E Controller, Waters 610 pump, Waters Inline Degasser, Waters

996 Photodiode Array Detector, Phenomenex Spherex 5 C18 Column(250 x 4.6 mm serial # 179224), and Peak Pro computer software.

The autosampler injected 20 ul of sample into the system and ran for 45 minutes at a flow rate of 1.2 ml/min. The heated column maintained a temperature of 35 °C. The mobile phase of the system was 0.01 M potassium phosphate monobasic (pH 3.1) and a mixture of 70 % acetonitrile and 30 % 0.01 M potassium phosphate monobasic. The two solutions used in the mobile phase were pumped into the system using a programmed linear gradient.

Thin layer chromatography. The peach sample was acidified to pH 2.5 using hydrochloric acid. A 50 ml peach sample was extracted three times v/v with hexane. The extract was extracted three more times v/v with ethyl acetate. All of the ethyl acetate extracts were combined and evaporated down and the residue was redissolved in 10 ml of water. The mixture was divided equally to make two separate extracts. The first extract consisted of 0.5 ml of 1 N hydrochloric acid added to 4.5 ml of peach extract. The acidified extract was heated in boiling water for one hour and allowed to cool. The peach extract hydrolysate was extracted three times v/v with ethyl acetate, evaporated, and redissolved in 0.5 ml of methanol. This acidic extract was used for thin layer chromatography.

The second extract consisted of adding 0.5 ml of 1 N sodium hydroxide to 4.5 ml of peach extract. The sample was purged with nitrogen and stored in a vacuum overnight at 25 °C. The solution was then acidified to pH 3.0 and extracted three times v/v with ethyl acetate. The ethyl acetate was evaporated and the residue was dissolved in 0.5 ml of methanol and used for thin layer chromatography.

Twenty microliters of acidic, basic, and raw peach extract were placed on a silica gel plate along with four standards. The standards were chlorogenic acid, p-hydroxycinnamic acid, ferulic acid, and caffeic acid. The plate was placed in solvent system for chromatographic separation using a solution of toluene, paradioxane, and acetic acid at a ratio of 90/25/4, respectively. The plate was allowed to run for one hour and analytes were located on the TLC plates with an ultraviolet light.

ANALYSIS OF VOLATILE COMPOUNDS

Gas chromatography was utilized to qualitatively examine volatile compounds in peach condensates and peach purees. Samples were prepared for analysis of volatile compounds by using an ethyl acetate extraction method. Fifty grams of peach sample was weighed out into a 250 ml fleaker. Then 200 ml of ethyl acetate was added and mixed thoroughly. The mixture was held overnight to obtain separation. Once two layers had formed, the top layer was carefully poured into a tube. The tube was then placed into a Zymark Turbo Vap II at 50 °C until it was concentrated to 0.5 ml. The tube was placed under the hood and allowed to cool. The liquid was pipetted out of the tube and placed into a B-D cc syringe and filtered through a Gelman Nylon Acrodisc 0.45 *u*m filter. Then 0.5 ml of ethyl acetate was used to rinse the tube, syringe and filter. The filtrate and wash was placed into a small vial and capped with a septum cap..

A gas chromatograph and mass spectrometer were used to analyze the peach samples. The equipment used was: a Varian 3400 Gas Chromatagraph, a Varian Saturn II Mass Spectrometer with methane chemical ionization and electron impact ionization, a DB-608, film thickness 0.50 *u*m, 30 m x .25 mm Column, a Varian 8100 Autosampler,

and a Saturn computer program. The autosampler injected 1.0 *u*l of sample into the system and ran for 20 minutes. The column was purged with pure methane gas to act as a buffer.

PREPARATION OF PUREE BLENDS

The product formulation is presented in figure 7. The puree and condensate were heated separately in stainless steal steam jacketed kettles. The puree and condensate were added to four once jars at different ratios to make different puree/condensate blends. The jars were capped using a white cap capper (model # VE 1424 LJG). All capped jars were placed into a water processing retort and cooked for a scheduled process (217 °F for 24 min.) to ensure commercial sterility.

ANALYSES OF PUREE BLENDS

The pH and total acidity were determined by using and Mettler Model DL 12 automatic titrator. A representative sample of 5 grams was placed into a cup and diluted with 30 ml of deionized water. This solution was titrated with 0.10 N NaOH to phenolphthalein end point (pH=8.1). Acidity of the sample was calculated in terms of percent concentration of malic acid.

Soluble solids (°B) was measured with a refractometer (Baush & Lomb Optical Co., Rochester, NY) using a representative sample at 25 °C.

The viscosity of the puree was measured by using a Brookfield Digital Viscometer (Model DV-II, Brook field Engineering Laboratories Inc., Stoughton, MA) using spindle RV 07 at 0.5 RPM and 25 °C.

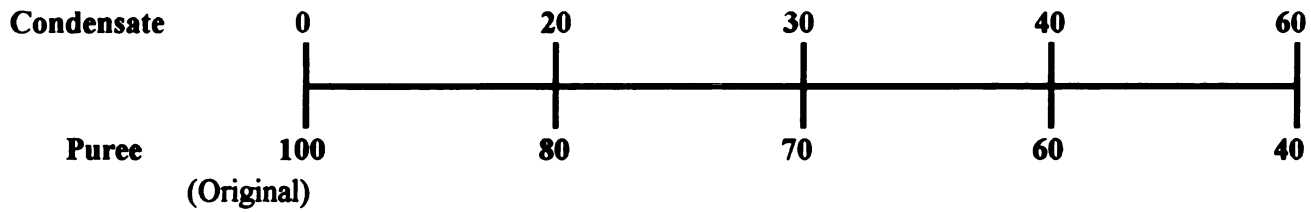


Figure 7 Dilution ratios of condensate and puree blends used for product formulation and utilization on low (LA; A-142) and high (HA; A-9) acid peach cultivars

The consistency of the puree was measured using a Bostwick consistometer and recorded as bostwick units (cm/5 sec) at the proceeding edge of the product after five seconds.

The color of the puree was measured by placing a sample into a custom-made cell using a Hunter Lab Color and Color difference meter (Model D25-PC2, Hunter Associates Laboratory, Inc., Reston, Virginia).

RESULTS AND DISCUSSION

MASS BALANCE

The initial weight of low acid raw peaches was 340.2 kg. The puree and condensate generated from the steam cooking process resulted in 118.8 kg of puree and 108.2 kg of condensate. This was a 34.9 % puree yield, 31.8 % condensate yield and 33.3 % loss of product due to pits, peels, and other process losses. The final retentate and final permeate generated from the ultrafiltration process resulted in 10.9 kg of retentate and 0.91 kg of permeate.

The initial weight of high acid raw peaches was 317.5 kg. The puree and condensate generated from the steam cooking process resulted in 128.8 kg of puree and 101.8 kg of condensate. This was a 40.6 % puree yield, 32.1 % condensate yield, and 27.3 % loss due to pit, peels, and other process losses. The final retentate and final permeate generated from the ultrafiltration resulted in 10.7 kg of retentate and 3.4 kg of permeate.

The mass balances for low acid peach samples and high acid peach samples are presented in figures 8 and 9, respectively.

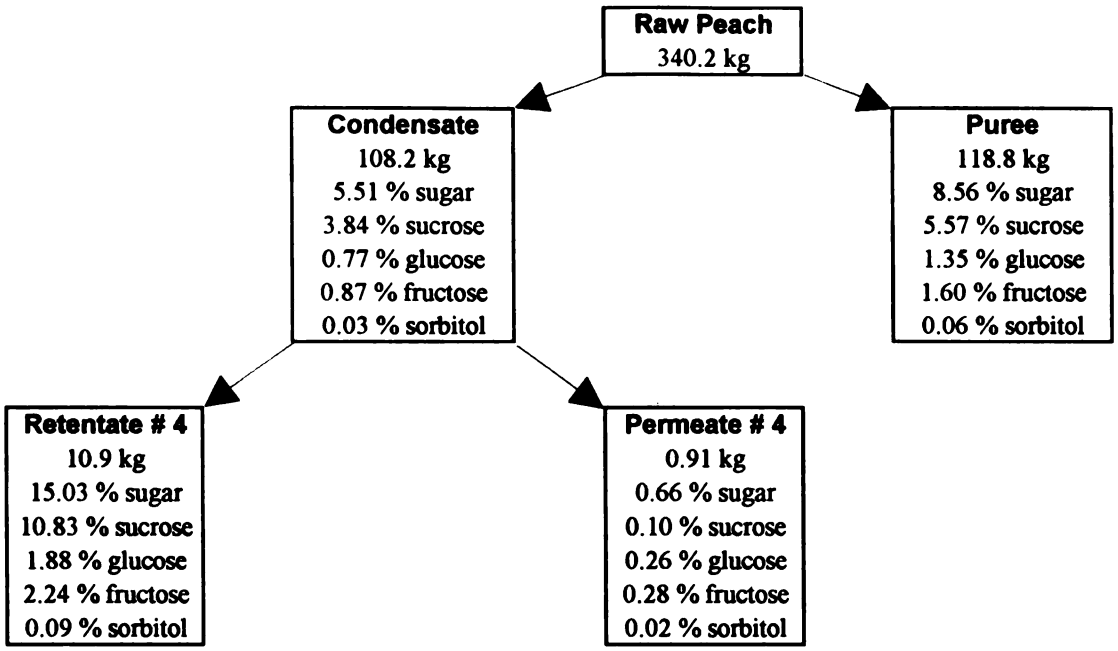


Figure 8 Mass balance of selected low acid peach samples illustrating the total and individual amount of sugars found in each sample

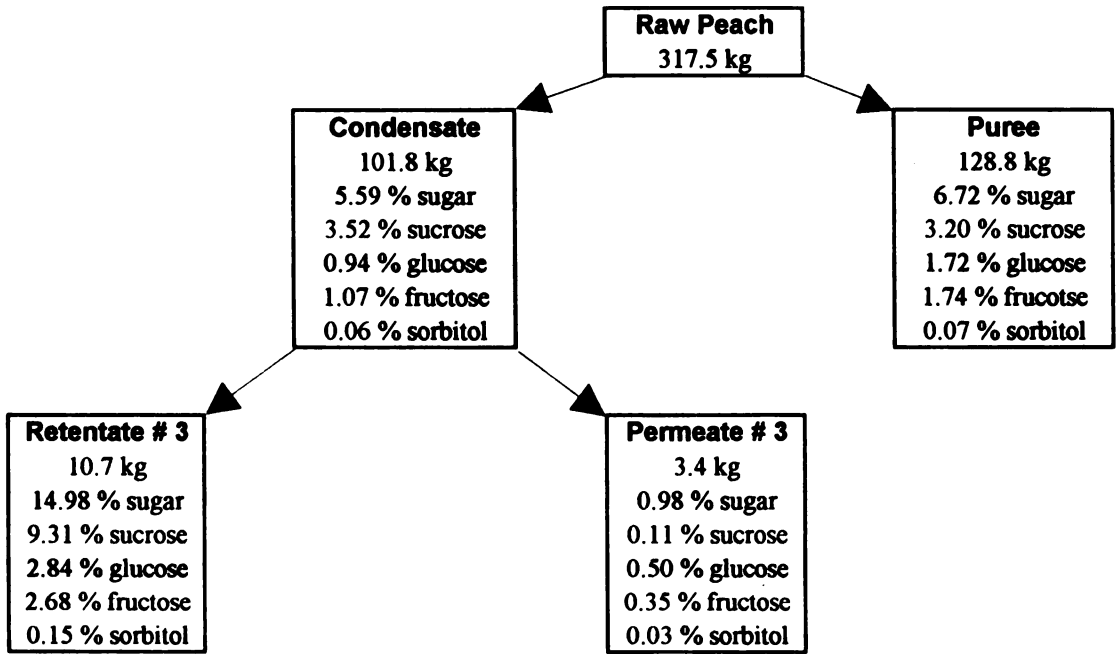


Figure 9 Mass balance of selected high acid peach samples illustrating the total and individual amount of sugars found in each sample

ANALYTICAL COMPONENTS OF CONDENSATE AND PUREE FRACTIONS

Sugars. Analyses were conducted on peach samples obtained from fractions generated from the ultrafiltration process. These samples were used to assess significant quantitative shifts in various sugars common to peach fruit. These changes may have dramatic influences on the flavor and color attributes of the final product. This study was focused on screening ultrafiltration fractions to appraise the relative impact on fraction profiles.

The mass balances for low acid peach samples and high acid peach samples each illustrating the total and individual amount of sugars found in each sample are presented in figures 8 and 9, respectively.

Low acid fractions. The total amount of sugar present in the low acid peach puree was 8.56 % sugar, which was greater than sugar found in the condensate (5.51 %). The retentate generated from passing the condensate through the ultrafiltration system resulted in 15.03 % total sugar. The ultrafiltration process increased the amount of sugar present by nearly three-fold. A minimal amount of sugar was lost in the permeate.

The predominant sugar found in all low acid peach samples was sucrose. The puree contained 5.57 % and the condensate contained 3.84 % sucrose. The retentate contained 10.83 % and the permeate contained 0.10 % sucrose. The next predominant sugar found in all low acid peach samples was fructose. The puree contained 1.60 % and the condensate contained 0.87 % fructose. The retentate contained 2.24 % and the permeate contained 0.28 % fructose. The third predominant sugar found in all low acid peach samples was glucose. The puree contained 1.35 % and the condensate contained 0.77 % glucose. The retentate contained 1.88 % and the permeate contained 0.26 %

glucose. A trace amount of sorbitol was found in all low acid peach samples. The puree contained 0.06 % and the condensate contained 0.03 % sorbitol. The retentate contained 0.09 % and the permeate contained 0.02 % sorbitol.

High acid fractions. The total amount of sugar present in the high acid peach puree was 6.72 % sugar, which was greater than sugar found in the condensate (5.59 %). The retentate generated from passing the condensate through the ultrafiltration system resulted in 14.98 % sugar. The ultrafiltration process increased the amount of sugar present by nearly three-fold. A minimal amount of sugar was lost in the permeate. The predominant sugar found in all high acid peach samples was sucrose. The puree contained 3.20 % and the condensate contained 3.52 % sucrose. The retentate contained 9.31 % and the permeate contained 0.11 % sucrose. The next predominant sugar found in some high acid peach samples was fructose. The puree contained 1.74 % and the condensate contained 1.07 % fructose. The retentate contained 2.68 % and the permeate contained 0.35 % fructose, which is less than the amount of glucose found in those samples. The third predominant sugar found in some high acid peach samples was glucose. The puree contained 1.72 % and the condensate contained 0.94 % glucose. The retentate contained 2.84 % and the permeate contained 0.50 % glucose. A trace amount of sorbitol was found in all high acid peach samples. The puree contained 0.07 % and the condensate contained 0.06 % sorbitol. The retentate contained 0.15 % and the permeate contained 0.03 % sorbitol.

Comparison of fractions by source. A graphical comparison of low and high acid peach samples is illustrated in figure 10. A comparison of low and high acid peach samples is presented in table 1.

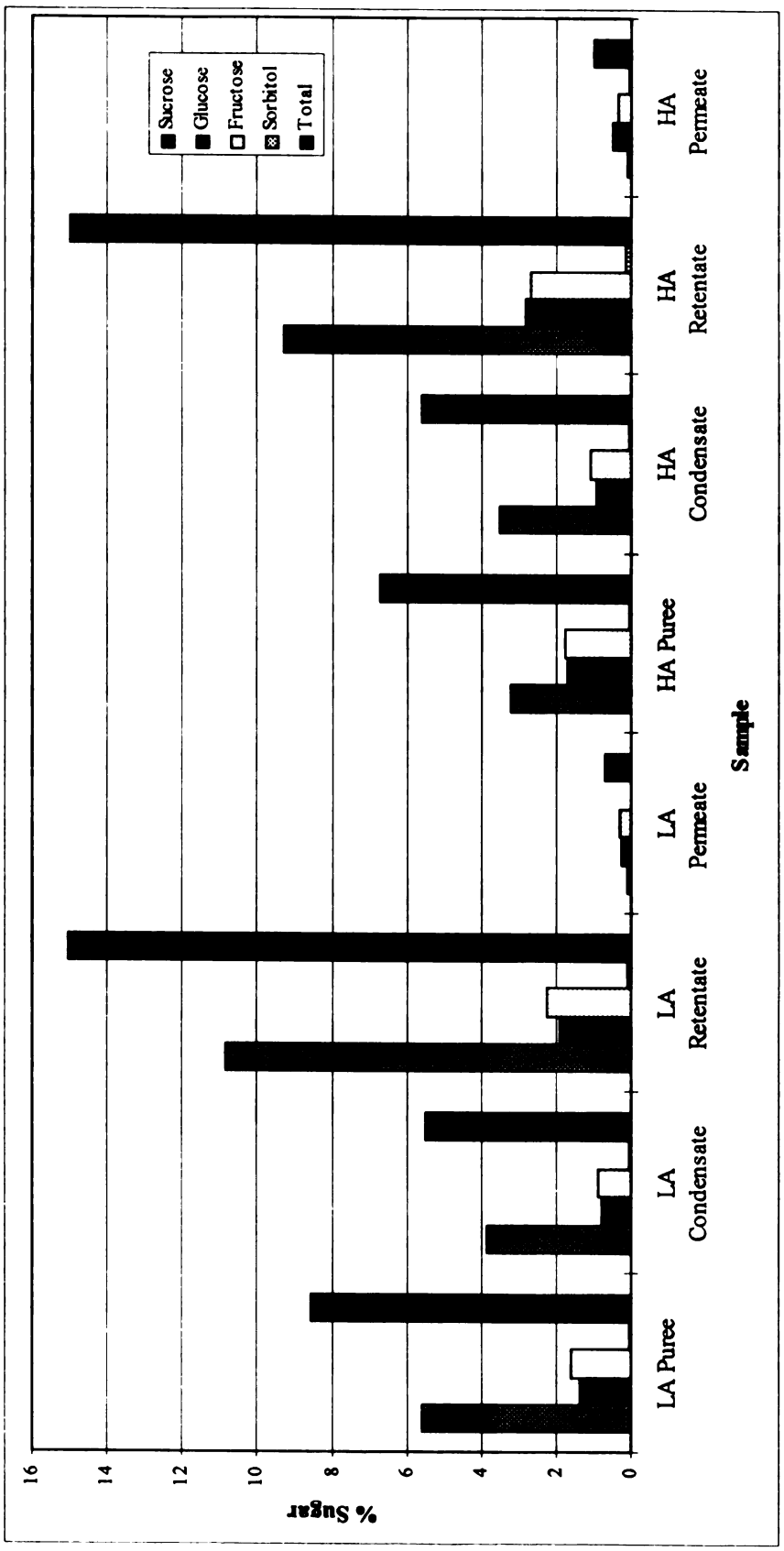


Figure 10 Comparison of low (LA; A-142) and high (HA; A-9) acid peach samples generated from the ultrafiltration of condensate fractions illustrating the total sugar content and individual levels of sucrose, glucose, fructose and sorbitol

Table 1 The effect of low and high acid peach puree, condensate, retentate, and permeate on total sugar and individual sugars including: sucrose, glucose, fructose, and sorbitol

Fraction	Source	Sugar (%)				
		Sucrose %	Glucose %	Fructose %	Sorbitol %	Total %
Puree						
	Low acid	5.57 ± 0.52	1.35 ± 0.06	1.60 ± 0.15	0.06 ± 0.01	8.56 ± 0.74
	High acid	3.20 ± 0.11	1.72 ± 0.0	1.74 ± 0.02	0.07 ± 0.01	6.72 ± 0.14
Condensate						
	Low acid	3.84 ± 0.07	0.77 ± 0.01	0.87 ± 0.01	0.03 ± 0.0	5.51 ± 0.09
	High acid	3.52 ± 0.09	0.94 ± 0.03	1.07 ± 0.06	0.06 ± 0.0	5.59 ± 0.12
Retentate						
	Low acid	10.83 ± 0.45	1.88 ± 0.06	2.24 ± 0.0	0.09 ± 0.01	15.03 ± 0.40
	High acid	9.31 ± 0.16	0.28 ± 0.11	2.68 ± 0.07	0.15 ± 0.01	14.98 ± 0.19
Permeate						
	Low acid	0.10 ± 0.0	0.26 ± 0.0	0.28 ± 0.0	0.02 ± 0.0	0.66 ± 0.0
	High acid	0.11 ± 0.0	0.50 ± 0.02	0.35 ± 0.01	0.03 ± 0.0	0.98 ± 0.03

Means and Standard Deviation; n=2

Organic acids. Analyses were conducted on peach samples obtained from fractions generated from the ultrafiltration process. These samples were used to asses significant quantitative shifts in various organic acids common to peach fruit. These changes may have dramatic influences on the flavor and color attributes of the final product. This study was focused to screening ultrafiltration fractions to appraise the relative impact on fraction profiles.

The mass balances for low acid peach samples and high acid peach samples each illustrating the individual amount of acid found in each sample are presented in figures 11 and 12, respectively.

The low acid puree contained 225.3 mg/100 g of malic acid and 67.0 mg/100 g of citric acid. The condensate contained 153.7 mg/100 g of malic and 81.7 mg/100 g of citric acid. The low acid retentate generated from the ultrafiltration process doubled the amount of malic acid content and almost doubled the citric acid content. The retentate contained 337.4 mg/100 g of malic and 154.2 mg/100 g of citric acid. The low acid permeate contained 154.2 mg/100 g of malic and 38.4 mg/100 g citric acid.

The high acid puree contained 435.8 mg/100 g malic acid and 295.6 mg/100 g of citric acid. The condensate contained 448.6 mg/100 g of malic and 313.0 mg/100 g of citric. The retentate generated from the ultrafiltration process contained 594.4 mg/100 g of malic and 594.1 mg/100 g of citric acid. The permeate contained 440.2 mg/100g of malic and 103.8 mg/100 g of citric acid.

A graphical comparison of all peach samples is presented in figure 13. The amount of acid present in the low acid peach samples is less than the amount of acid present in the

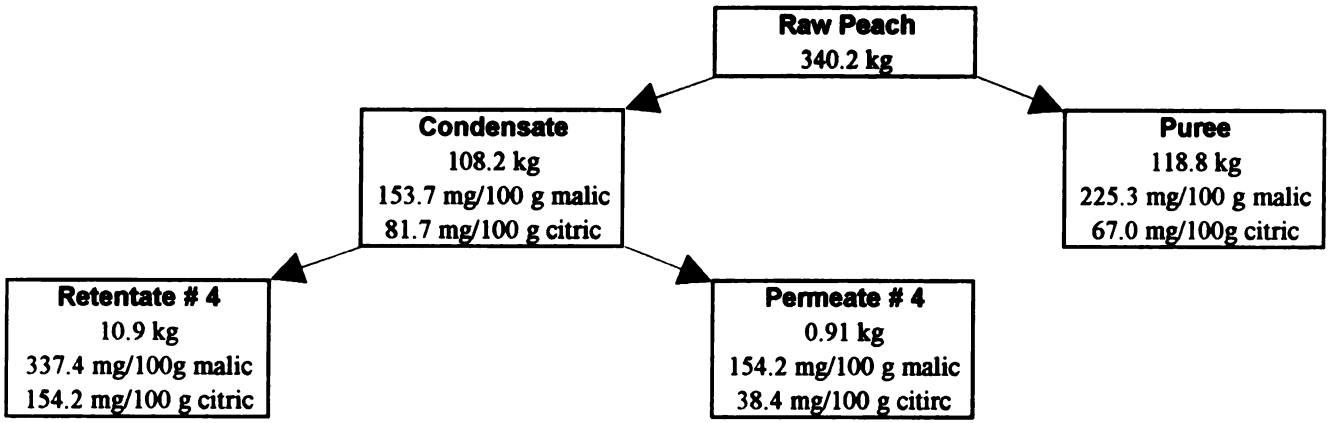


Figure 11 Mass balance of selected low acid peach samples illustrating the individual amounts of malic and citric acid found in each fraction

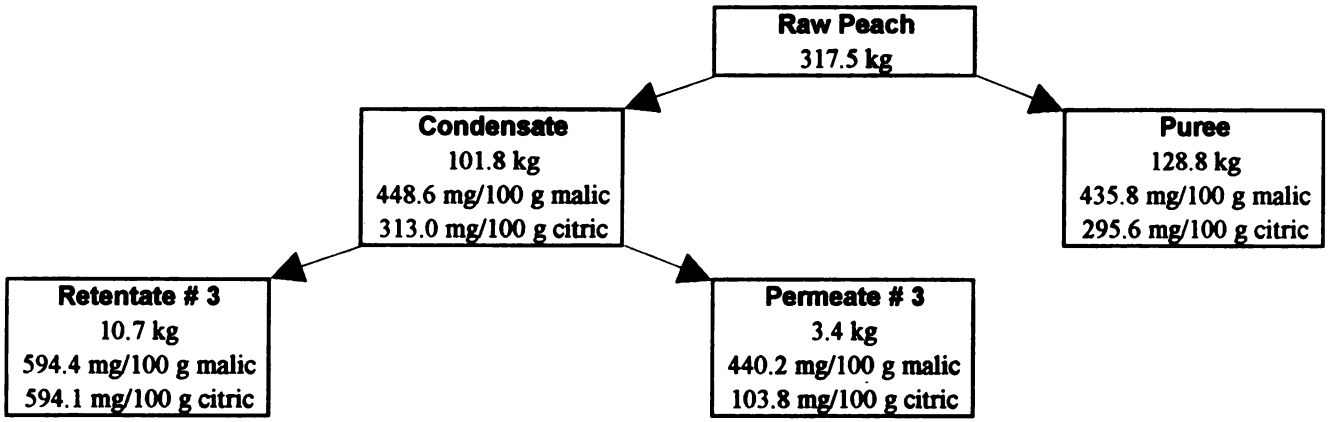


Figure 12 Mass balance of selected high acid peach samples illustrating the individual amounts of malic and citric acid found in each fraction

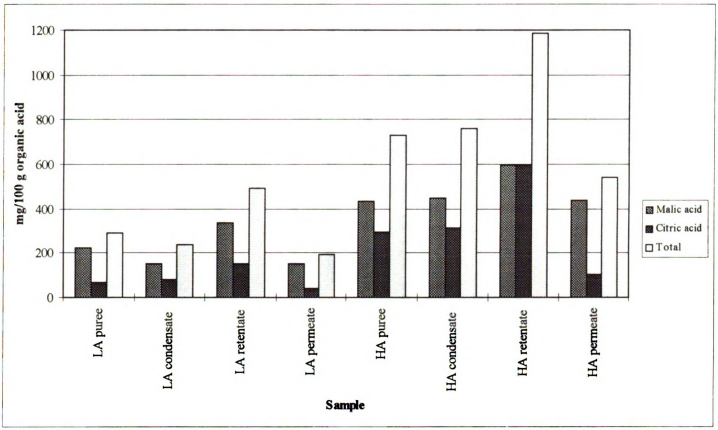


Figure 13 Comparison of low acid (LA; A-142) and high acid (HA; A-9) peach samples and condensate fractions generated from the ultrafiltration of condensate illustrating the total organic acid content and each individual level of malic and citric acid

high acid peach samples. Meredith et al. (1989) concluded that peaches ripened for a longer period of time had a decrease in acid concentration. At full maturity two clingstone cultivars, Babygold 5 and Babygold 7 contained 60 % malic, 20 % citric, and 19 % quinic acid. During fruit ripening, both cultivars increased in malic acid and decreased in citric acid and quinic acids (Wang et al., 1993).

Polyphenolic Compounds. Analyses were conducted to assess significant qualitative shifts in phenolics due to ultrafiltration and to evaluate relative quantitative changes among fractions. These changes may have dramatic influences in product flavor or color attributes. This study was focused to screening ultrafiltration fractions to appraise the relative impact on fraction profiles.

Polyphenols were run on eight peach samples: low acid puree, low acid condensate, low acid retentate, low acid permeate, high acid puree, high acid condensate, high acid retentate, and high acid permeate. The high pressure liquid chromatograms of low and high acid peach samples is presented in figures 14 and 15. Two major peaks were found in each of the eight samples.

Peak one was not identified using the high pressure liquid chromatography. Further investigation using thin layer chromatography indicated that the first peak is likely to be caffeic acid. Trace amounts of ferulic acid were also detected.

The second peak at an elution time of 26 minutes was identified as chlorogenic acid. Senter and Callahan (1990) identified chlorogenic acid, neochlorogenic acid, isochlorogenic acid, catechin, and epicatechin as the major monomeric phenols present in all peach cultivars studied.

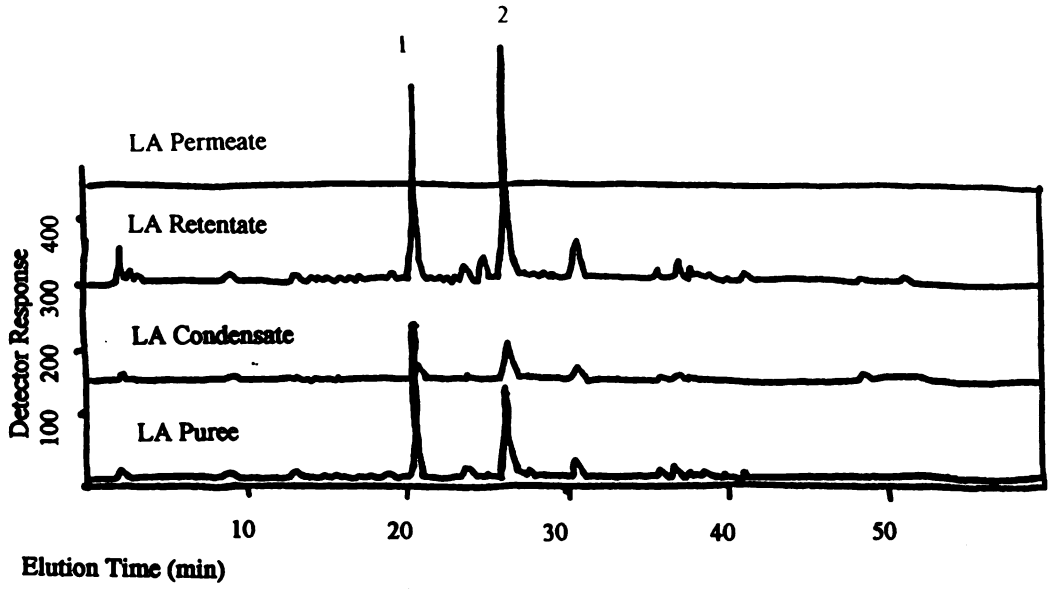


Figure 14 HPLC chromatograms of low acid (LA;A-142) peach puree, condensate, retentate, and permeate to detect phenolic compounds

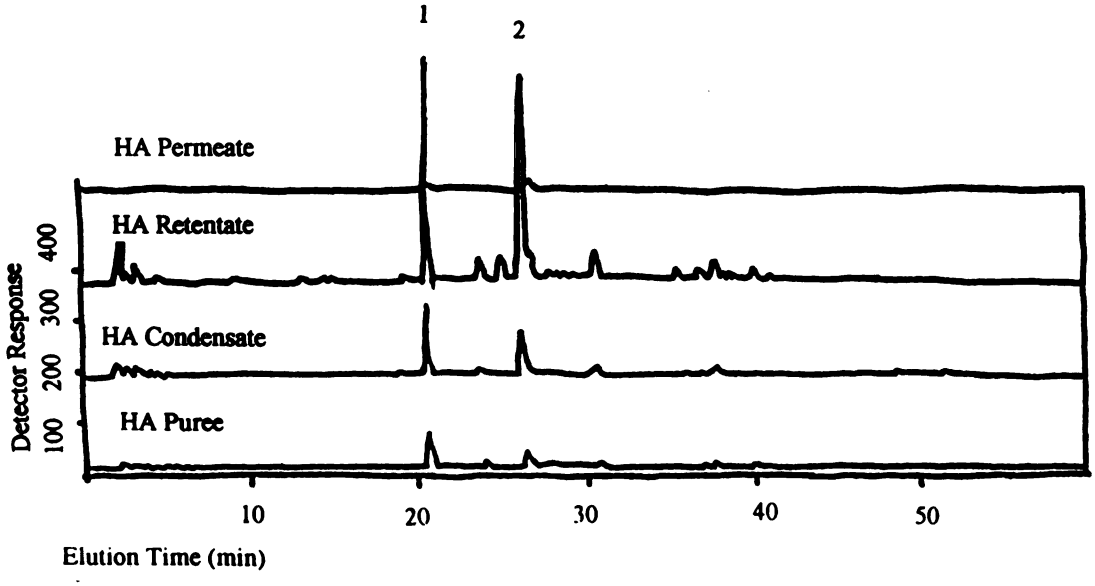


Figure 15 HPLC chromatograms of high acid (HA; A-9) peach puree, condensate, retentate, and permeate to detect phenolic compounds

Results of low and high acid peach samples indicated greater levels of phenolic compounds present in high acid samples (figure 15) than low acid samples (figure 14). Luh et al.(1967) found four chlorogenic acid isomers, five leucoanthocyanidin isomers, catechin, epicatechin, isoflavone, two p-coumarylquinic acids, and caffeic acid in canned cling peaches. Chlorogenic acids, leucoanthocyanidins, and catechin were present in the largest quantities.

Results of the low acid samples indicated greater quantities of phenolic compounds present in the puree than in the condensate. Greater quantities of phenolic compounds where present in the retentate than in the condensate or the puree. Indicating the ultrafiltration process has increased the total amount of phenolic compounds present.. There was about a four fold enrichment in phenolic content from the condensate to retentate. This was expected due to the presence of only trace amounts that were found in the permeate. Thus, phenolic compounds were not transmitted across the membrane due to possible cross-linkage with macro molecules in the puree.

Results of the high acid samples indicated greater quantities of phenolic compounds present in the condensate than the puree. Thus, the cooking process resulted in selective extraction of phenolic compounds which generally impact bitter astringent taste characteristics. There were greater quantities of phenolic compounds present in the retentate than in the condensate or the puree. The ultrafiltration process increased the phenolic content by about three-fold. Only trace amounts of phenols were present in the permeate.

Volatile Compounds. Analyses were conducted to assess significant qualitative shifts in volatile compounds due to ultrafiltration and to evaluate relative quantitative

changes among fractions. These changes may have dramatic influences on product flavor or color attributes. This study was focused to ultrafiltration screening on the relative impact of fraction profiles.

The gas chromatogram of low acid peach puree is presented in figure 16. The low acid peach puree has eight numbered peaks. The gas chromatogram of low acid condensate is presented in figure 17. Two numbered peaks are present in the low acid condensate. The gas chromatogram of low acid retentate is presented in figure 18. The low acid retentate has eleven numbered peaks. The gas chromatogram of low acid permeate is presented in figure 19. The low acid permeate has ten numbered peaks.

A peach aldehyde was identified and numbered as peak seven. This peach aldehyde was the only compound present in all of the low acid peach samples. The amount present in the condensate is greater than that present in the permeate. The amount present in the puree is greater than that present in the condensate. The amount present in the retentate is greater than that present in the puree. Thus, the ultrafiltration process has increased the amount of peach aldehyde in the retentate.

Peaks numbered one, six, and nine were identified as alcohol's. Peaks numbered five and eight were identified as aldehdyes. Peak two was identified as an acid. Peak four was identified as an ester. Peaks ten, eleven, and twelve were identified as low volatile compounds.

In general, the low acid retentate had the largest peaks of all the low acid peach chromatograms. Thus, indicating a greater quantity of volatiles present in the retentate.

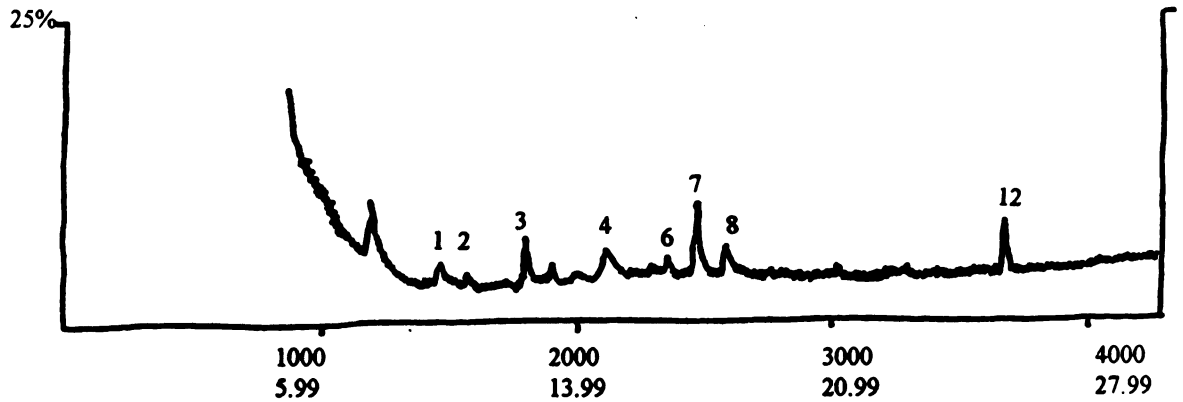


Figure 16 Gas chromatogram of low acid (LA;A-142) peach puree detecting various compounds which comprise a flavor profile

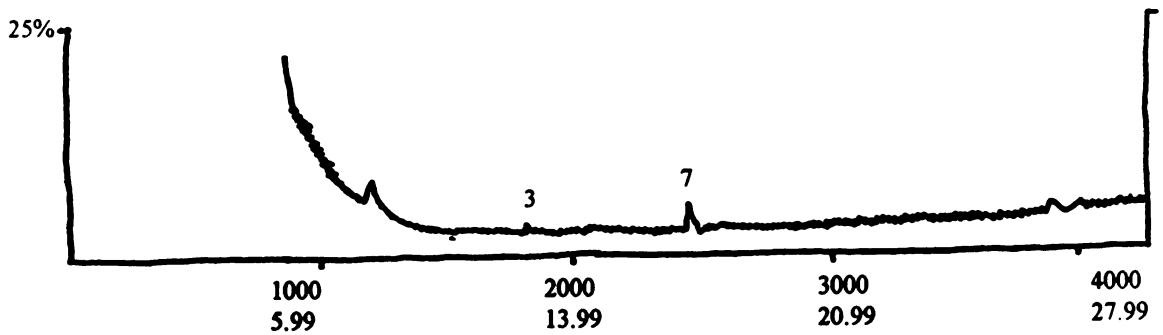


Figure 17 Gas chromatogram of low acid (LA;A-142) condensate detecting various compounds which comprise a flavor profile

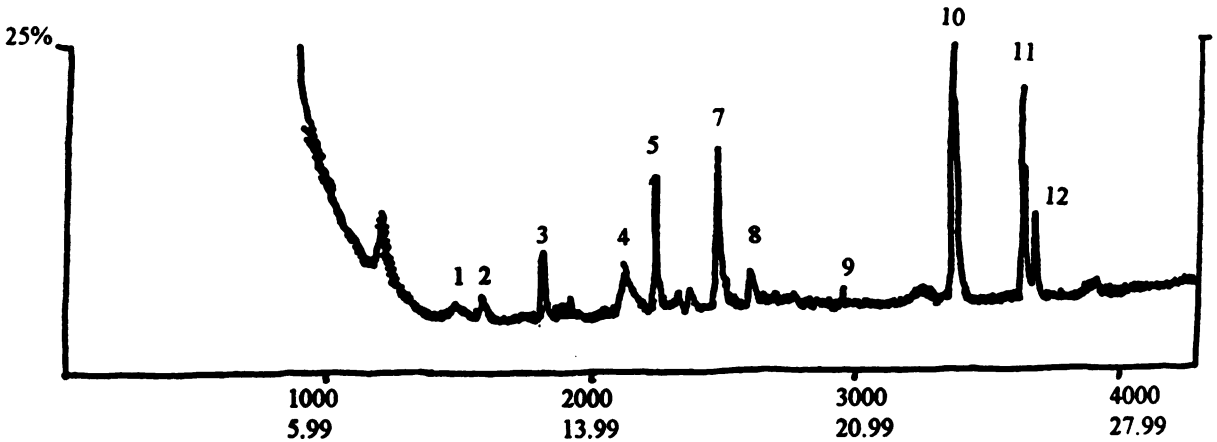


Figure 18 Gas chromatogram of low acid (LA;A-142) retentate detecting various compounds which comprise a flavor profile

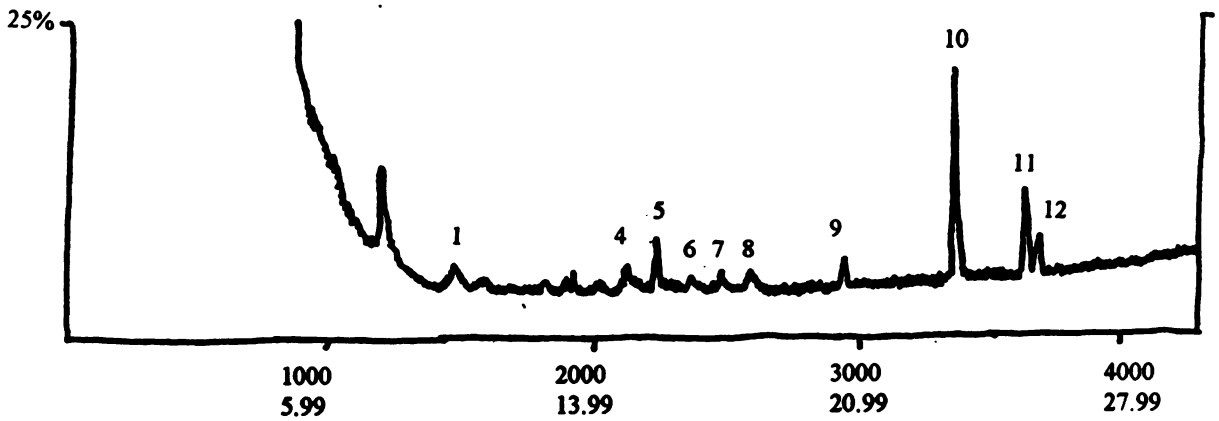


Figure 19 Gas chromatogram of low acid (LA;A-142) permeate detecting various compounds which comprise a flavor profile

The gas chromatogram of high acid peach puree is presented in figure 20. The high acid peach puree has six numbered peaks. The gas chromatogram of high acid condensate is presented in figure 21. Five numbered peaks are present in the high acid condensate. The gas chromatogram of high acid retentate is presented in figure 22. The high acid retentate has five numbered peaks. The gas chromatogram of high acid permeate is presented in figure 23. The high acid permeate did not posses any detectable volatile compounds. Peaks one, two, and four were identified as low molecular weight alcohol's. Peak three was identified as an ester. Peak five was identified as an alcohol, which is a natural volatile of peach. Peak six was identified as an aldehyde. The size of the peaks in the high acid retentate were greater than the peaks of the puree and condensate. Thus, indicating a larger quantity of volatiles present in the retentate.

Jennings and Sevenants (1964) and Sevenants and Jennings (1966) studied the volatile components of a Red Globe variety freestone peach. They used two gas chromatographic columns and infrared spectroscopy to identify twenty four volatile compounds. The compounds identified included: acetaldehyde, methyl acetate, ethyl acetate, ethyl alcohol, hexyl formate, hexyl acetate, trans-2-hexenyl acetate, hexyl alcohol, acetic acid, trans-2-hexene-1-ol, benzaldehyde, isovaleric acid, ethyl benzoate, gamma-caprolactone, benzly acetate, gamma-heptalactone, caproic acid, benzyl alcohol, gamma-octalactone, gamma-nonalactone, hexyl benzoate, gamma decalactone, alpha-pyrone, and delta-decalactone. They concluded that individual compounds had their own distinct odor. For example, the lactones were characterized by a coconut odor. They suggested that the typical peach aroma is not due to one or two compounds, but it is made of a wide

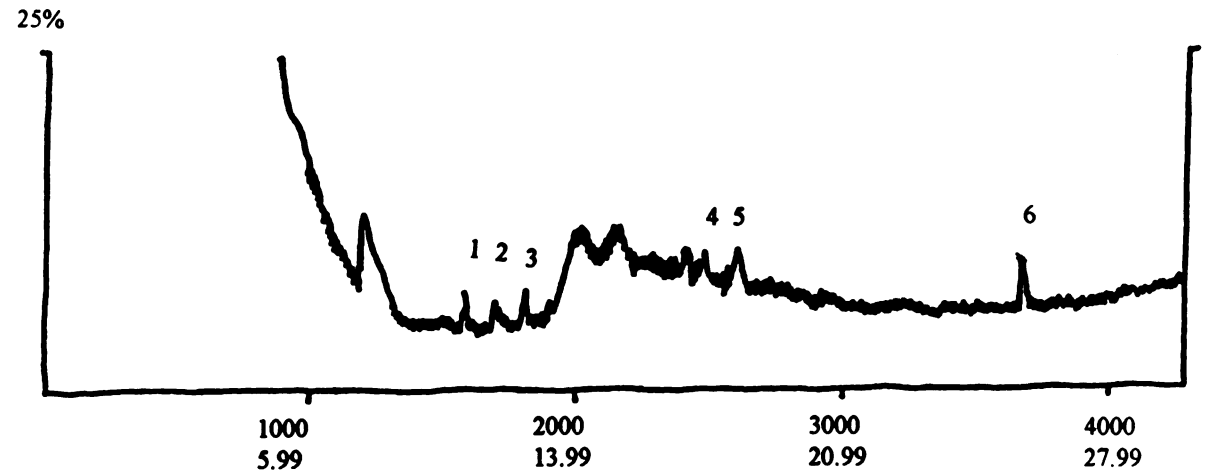


Figure 20 Gas chromatogram of high acid (HA;A-9) peach puree detecting various compounds which comprise a flavor profile

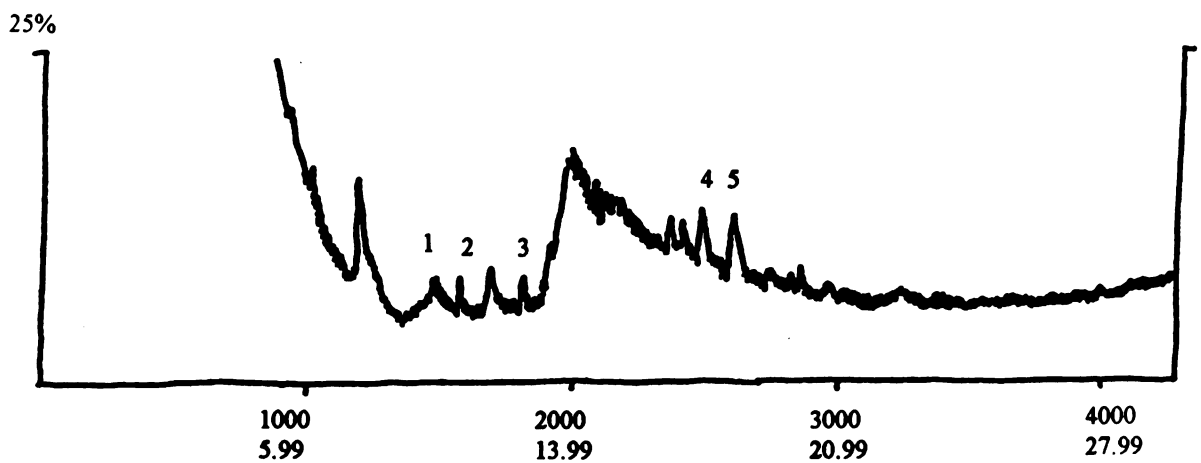


Figure 21 Gas chromatogram of high acid (HA;A-9) condensate detecting various compounds which comprise a flavor profile

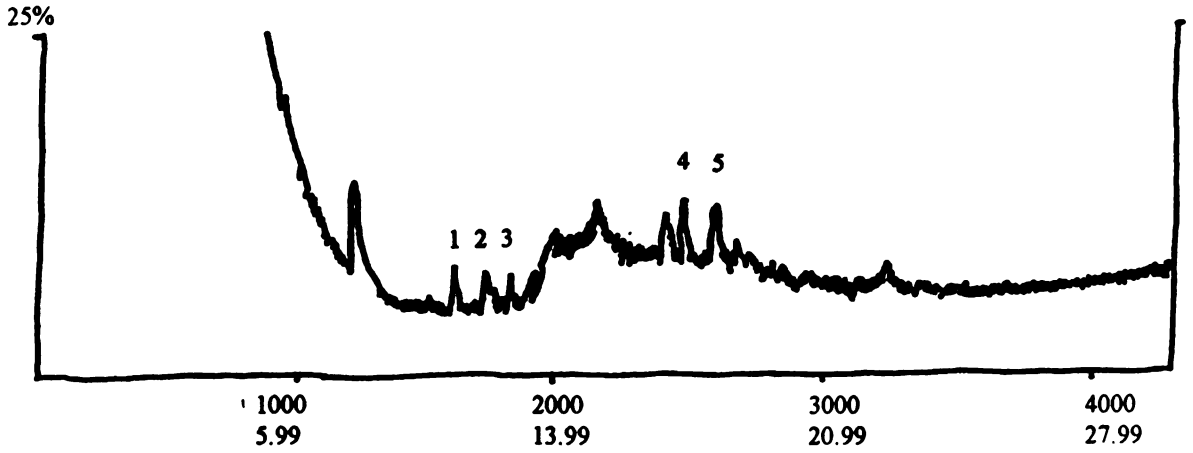


Figure 22 Gas chromatogram of high acid (HA;A-9) retentate detecting various compounds which comprise a flavor profile

Figure 23 Gas chromatogram of high acid (HA;A-9) permeate detecting various compounds which comprise a flavor profile

spectrum of compounds whose individual aromas are not at all peach-like. Do et al. (1969) identified the major volatile components of peach as gamma- and delta-lactones, esters, aldehydes, benzyl alcohol, and d-limonene. The highest total lactone concentration occurred in tree-ripe peaches and was more than four times that of firm-mature fruit. Meredith et al. (1989) compared the volatile concentrates of Harvester peaches at two different maturity stages using gas-liquid chromatography. The more mature fruit contained several different types of chemical constituents related to peach flavor. These included the hexenal-hexenol, linalool-nonanal, and gamma-decalactone. These compounds were not present in the immature fruit. The immature fruit contained only C_{23} and C_{25} hydrocarbons. They concluded that peaches ripened for seven days had an increase in volatile components related to flavor.

The low acid puree had greater levels of volatile components than the high acid puree. Indicating more flavor components in the low acid puree. Thus, the flavor and aroma of the low acid puree will be more desirable than the high acid puree. The low acid peach condensate contained less volatiles than the high acid condensate. The amount of volatiles present in the high acid condensate must have maintained their integrity and were not lost in the steam cooking process.

The ultrafiltration system increased the total amount of volatiles present in both the low and high acid samples. The low acid retentate had seven more compounds than the high acid sample. The ultrafiltration system magnified the amount of volatiles present in the condensate. Only two components were visible in the condensate, but after ultrafiltration twelve components were visible. Many of the components present in the retentate were also present in the puree, indicating an increased amount of flavor and

aroma captured in the condensate, but were magnified in the retentate. The high acid retentate had the same amount of peaks, but the peaks were larger and more defined, indicating an increase in flavor and aroma volatiles, but on a smaller scale than the low acid retentate. The low and high acid retentates increased the amount of volatile components present. Thus, the final puree blend should be more desirable with these enhanced flavor and aroma volatiles.

No volatiles were present in the high acid permeate. Thus, no loss of volatiles to the ultrafiltration system occurred in the high acid permeate. Some of the same volatiles were present in the low acid permeate as the low acid retentate. The volatiles present in the permeate were less than that in the retentate, indicating a greater concentration in the retentate than in the permeate after passing through the ultrafiltration system. The small amount of volatiles present indicates that the ultrafiltration system is not allowing only volatiles to pass to the retentate, but also to the permeate.

ANALYTICAL COMPONENTS OF FINAL PUREE BLENDS

Analyses were conducted to assess the ratio of condensate added back to the puree and evaluate the significant quantitative changes among puree blends. These changes may have dramatic influences on product flavor and color attributes.

Figure 6 illustrates the ratio of condensate and puree added at varying amounts. Both low and high acid puree and condensate were added at the same ratios. The results of pH, total acidity, soluble solids, soluble solids/acid ratio, viscosity, consistency, and Hunter color values are presented in table 2. These results are consistent with the trends associated with the dilution blends of the original materials.

Table 2 Results of chemical and phsyical analyses of processed low (LA) and high (HA) acid peach puree with the addition of ultrafiltrated condensate added back at varying amounts

Puree Blend						Rheological Properties		Hunter Color Values [4]					
Condensate		pH	Total	SS[2]	SS/Acid	Viscosity(cP)	Consistency[3]	L	a_L	b_L	L*	C*	Ha
%	Source		Acidity[1] (%)	(B)	Ratio	x 1000	(cm / 5 sec.)						
0 %	LA	4.16	0.28	11.3	40	1493.3	6.33	41.4	9.4	23.3	48.4	47.8	76.1
20 %	LA	4.22	0.31	14.1	45	909.7	8.92	39.1	9.2	21.9	46.1	46.0	75.5
30 %	LA	4.25	0.33	15.4	46	703.3	10.50	38.5	9.4	21.6	45.4	45.6	75.1
40 %	LA	4.26	0.36	17.0	48	468.0	12.33	37.2	8.9	20.8	44.0	44.4	75.3
60 %	LA	4.28	0.39	19.7	50	153.3	21.00	34.2	8.7	19.0	40.7	41.6	74.2
0 %	HA	3.62	0.94	12.5	13	1840.0	5.08	42.0	9.5	22.4	49.1	44.2	74.7
20 %	HA	3.70	1.00	14.9	15	1056.7	7.67	40.1	9.6	21.5	47.1	43.4	74.1
30 %	HA	3.71	1.05	16.3	15	816.0	8.83	38.9	9.4	20.8	45.8	42.4	74.0
40 %	HA	3.73	1.10	17.7	16	508.0	11.58	37.7	9.4	20.2	44.6	41.7	73.5
60 %	HA	3.74	1.23	21.3	17	149.3	19.08	33.7	9.5	18.0	40.2	39.0	71.5

n=3

[1]Acidity expressed as % Malic (0.067g/meq); [2]Soluble Solids; [3]Bostwick Units; [4]Hunter Lab Values L=Lightness, a_L=Greenness, b_L=Yellowness; L*=Lightness(International Scale); C*=Chroma; Ha=Hue Angle

The pH of the low acid puree blends ranged from 4.16 to 4.28. The pH of the high acid puree blends ranged from 3.62 to 3.74. The total acidity of the low acid puree blends ranged from 0.28 to 0.39. The total acidity of the high acid puree blends ranged from 0.94 to 1.23. The pH and total acidity increased in both low and high acid puree blends with an increase in the amount of condensate added. The high acid puree blends were three times greater in total acidity than the low acid puree blends. A comparison of pH and total acidity of low and high acid puree blends is illustrated in figure 24.

The soluble solids of low acid puree blends ranged from 11.3 to 19.7 °B. The soluble solids of high acid puree blends ranged from 12.5 to 21.3 °B. The soluble solids/acid ratio of low acid puree blends ranged from 40 to 50. The soluble solids/acid ratio of high acid puree blends ranged from 13 to 17. Thus, the soluble solids increased in both low and high acid puree blends, but the overall sweetness of the final puree did not dramatically increase. A comparison of soluble solids, soluble solids/acid ratio, and total acidity of low and high acid puree blends is illustrated in figure 25.

The Hunter color value of lightness ranged from 41.4 to 34.2 in the low acid puree blend. The high acid puree blend ranged from 42.0 to 33.7. The Hunter color value of greenness ranged from 9.4 to 8.7 in the low acid puree blend. The high acid puree blend ranged from 9.6 to 9.4. The Hunter color value of yellowness in the low acid puree blend ranged from 23.3 to 19.0. The high acid puree blend ranged from 22.4 to 18.0. A comparison of hunter color values is illustrated in figure 26. The lightness of the puree blends decreased as more condensate was added in both low and high acid puree blends. The greenness of the puree blends stayed relatively constant in both the low and high acid puree blends. The yellowness of the puree blends decreased as more condensate was

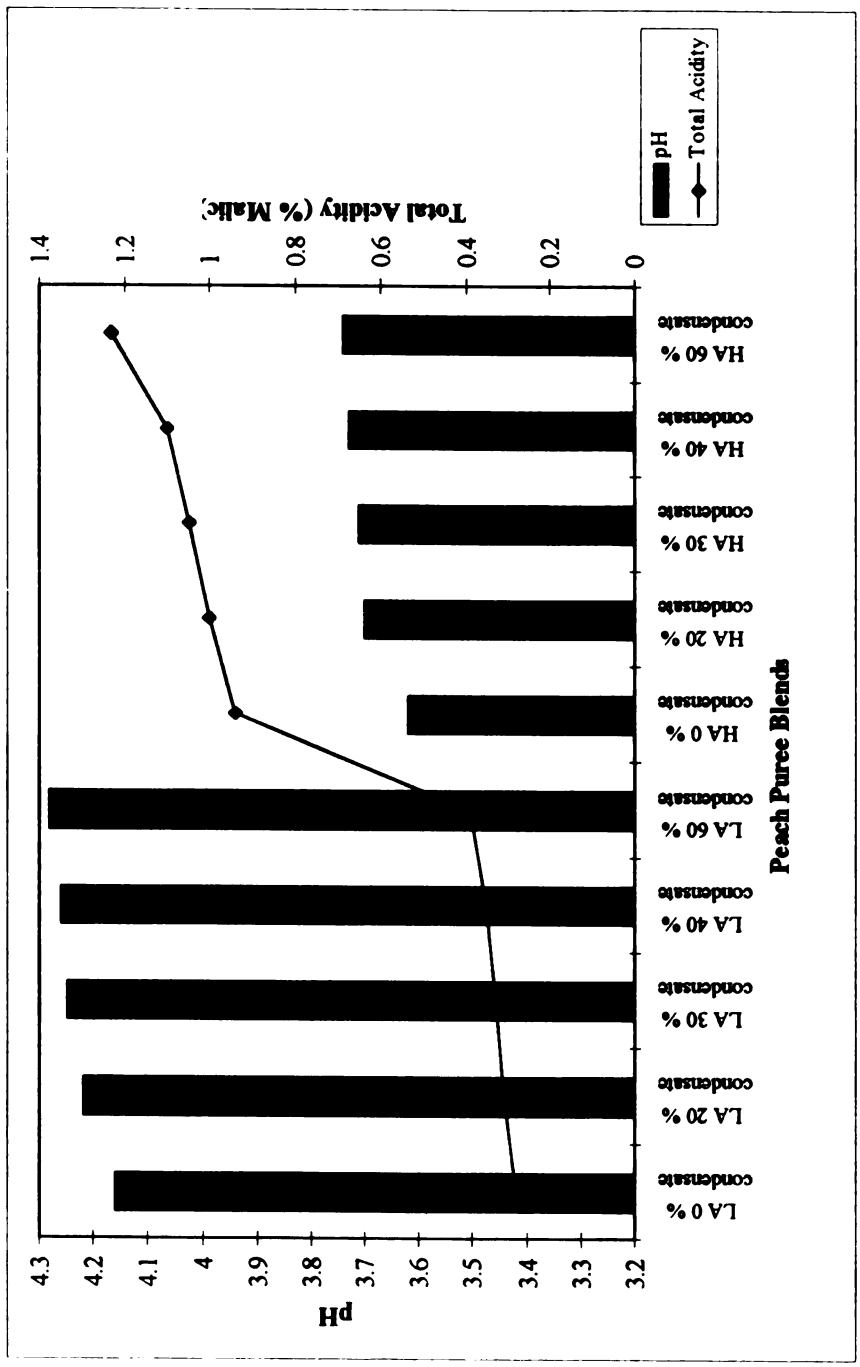


Figure 24 Total acidity (% malic) and pH of processed low (LA) and high (HA) acid peach puree with the addition of ultrafiltrated condensate added back at varying amounts

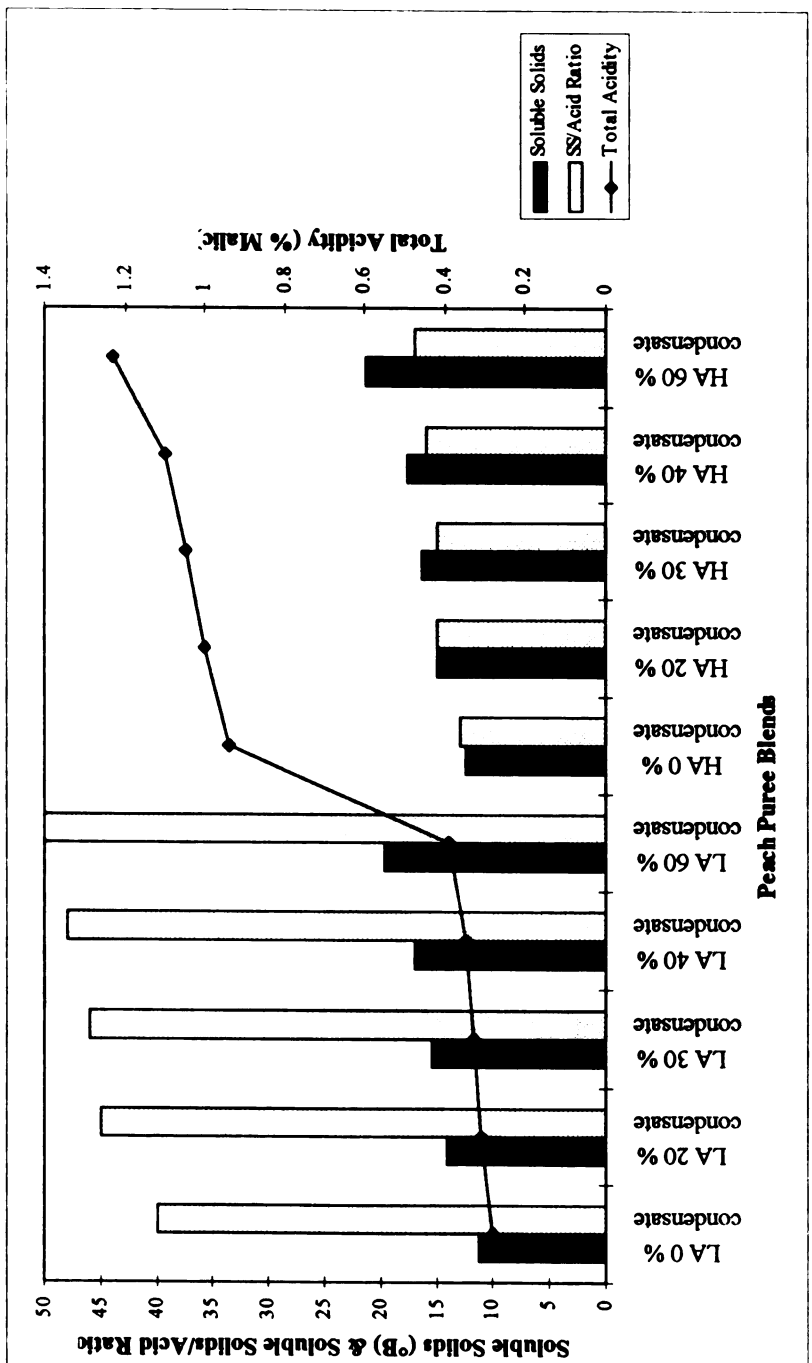


Figure 25 Total acidity (% malic), soluble solids (°B), and soluble solids/acid ratio of processed low (LA) and high (HA) acid peach puree with the addition of ultrafiltrated condensate added back at varying amounts

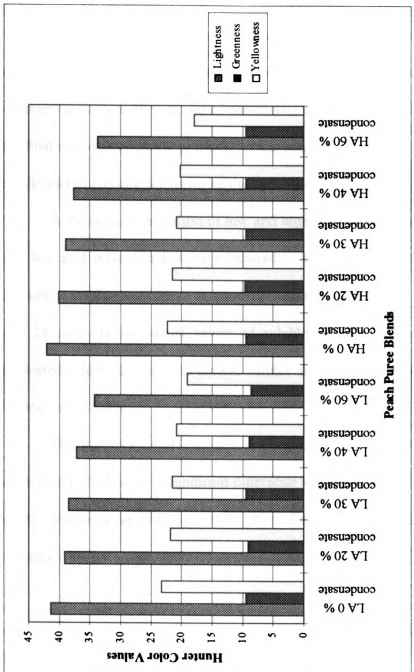


Figure 26 Color attributes (lightness, greenness, yellowness) of processed low (LA) and high (HA) acid peach puree with the addition of ultrafiltrated condensate added back at varying amounts

added in both low and high acid puree blends. The trends of decreasing lightness and yellowness in both low and high acid puree blends indicated that puree was more yellow and lighter in color than the condensate.

The viscosity of the puree blends decreased with the addition of condensate. The decrease in viscosity was expected with an increase in condensate being added back. In a commercial process, the amount of condensate that is added back would be determined by the final consistency of the product. Thus, limiting the amount of condensate that would be allowed to enhance the flavor of the final product.

A statistical comparison of low and high acid puree blends is presented in table 3. The low acid puree blends were compared to the high acid puree blends based upon the amount of condensate added. A statistical summary is presented in table 4. Figures 27 and 28 illustrate the actual values of soluble solids and soluble solids/acid ratio vs. estimated values of soluble solids and soluble solids/acid ratio of low and high acid puree blends, respectively.

The analyses of pH, total acidity, soluble solids, soluble solids/acid ratio, and consistency all showed a significant difference between low acid 0 %, 20 %, 30 %, 40 %, 60 % condensate, and high acid 0 %, 20 %, 30 %, 40 %, 60 % condensate by analysis of variance (ANOVA ; $p>0.05$).

Table 3 The effect of processed low (LA) and high (HA) acid peach puree with the addition of ultrafiltrated condensate added back at varying percentages on pH, total acidity, soluble solids, soluble solids/acid ratio, viscosity, consistency, and Hunter color values (L, a_L, b_L,)

Puree Blend						Rheological Properties		Hunter Color Values [4]		
Condensate		pH	Total	SS[2]	SS/Acid	Viscosity(cP)	Consistency[3]	L	a_L	b_L
%	Source		Acidity[1] (%)	(B)	Ratio	x 1000	(cm / 5 sec.)			
0%		3.90 A	0.62 A	11.9 A	27 A	1666.6 A	5.71 A	41.6 A	9.5 B	22.8 A
	LA	4.16 a	0.28 a	11.3 a	40 a	1493.3 a	6.33 a	41.4 a	9.4 a	23.3 a
	HA	3.62 b	0.94 b	12.5 b	13 b	1840.0 b	5.08 b	42.0 a	9.5 a	22.4 b
20%		3.96 B	0.66 B	14.5 B	30 B	983.2 B	8.29 B	39.6 B	9.4 AB	21.7 B
	LA	4.22 a	0.31 a	14.1 a	45 a	909.6 a	8.92 a	39.1 a	9.2 a	21.9 a
	HA	3.70 b	1.00 b	14.9 b	15 b	1056.6 b	7.67 b	40.1 b	9.6 b	21.5 b
30%		3.98 C	0.69 C	15.9 C	31 C	759.6 C	9.67 C	38.7 C	9.4 AB	21.3 C
	LA	4.25 a	0.33 a	15.4 a	46 a	703.3 a	10.5 a	38.5 a	9.4 a	21.6 a
	HA	3.71 b	1.05 b	16.3 b	15 b	816.0 a	8.83 b	38.9 a	9.4 a	20.8 a
40%		3.99 CD	0.73 D	17.4 D	32.5 D	488.0 D	12.0 D	37.4 D	9.2 AB	20.6 D
	LA	4.26 a	0.36 a	17.0 a	48 a	468.0 a	12.33 a	37.2 a	8.9 a	20.8 a
	HA	3.73 b	1.10 b	17.7 b	16 b	508.0 a	11.58 b	37.7 a	9.4 b	20.2 a
60%		4.01D	0.82 E	20.5 E	34 E	151.0 E	20.1 E	34.0 E	9.1 A	18.5 E
	LA	4.28 a	0.39 a	19.7 a	50 a	153.3 a	21.0 a	34.2 a	8.7 a	19.0 a
	HA	3.74 b	1.23 b	21.3 b	17 b	149.3 a	19.08 b	33.7 a	9.5 b	18.0 b

Means (n=3) within a column followed by different letters indicate significant difference ($p<0.05$): paired comparisons within condensate source treatments (lower case); multiple comparisons (Fisher's PLSD) across puree blends, means of condensate treatment (upper case)

[1]Acidity expressed as % Malic (0.067g/meq); [2]Soluble Solids; [3]Bostwick Units; [4]Hunter Lab Values L=Lightness, a_L=Greenness, b_L=Yellowness

Table 4 Processed low and high acid peach puree- pH, total acidity, soluble solids, soluble solids/acid ratio, viscosity, consistency, and Hunter color values analysis of variance (ANOVA) statistical summary

		pH	Total acidity	Soluble solids	SS/acid ratio	Viscosity	Consistency	L	a_L	b_L
Source	DF	MS	MS	MS	MS	MS	MS	MS	MS	MS
Level	4	0.012 *	0.35 *	61.861 *	43.97 *	195.5×10^{10} *	179.5 *	49.56 *	0.153	15.46 *
Treatment	1	2.160 *	4.033 *	5.985 *	7022.7 *	12.4×10^{10} *	14.0 *	1.37 *	0.94 *	3.96 *
L X T	4	9.2×10^{-5} *	0.007 *	0.387 *	13.2 *	2.80×10^{10} *	0.30 *	0.43	0.14	0.64
Error	20	9.17×10^{-5}	1.23×10^{-4}	0.44	0.30	$.213 \times 10^{10}$	0.042	0.195	0.071	0.086

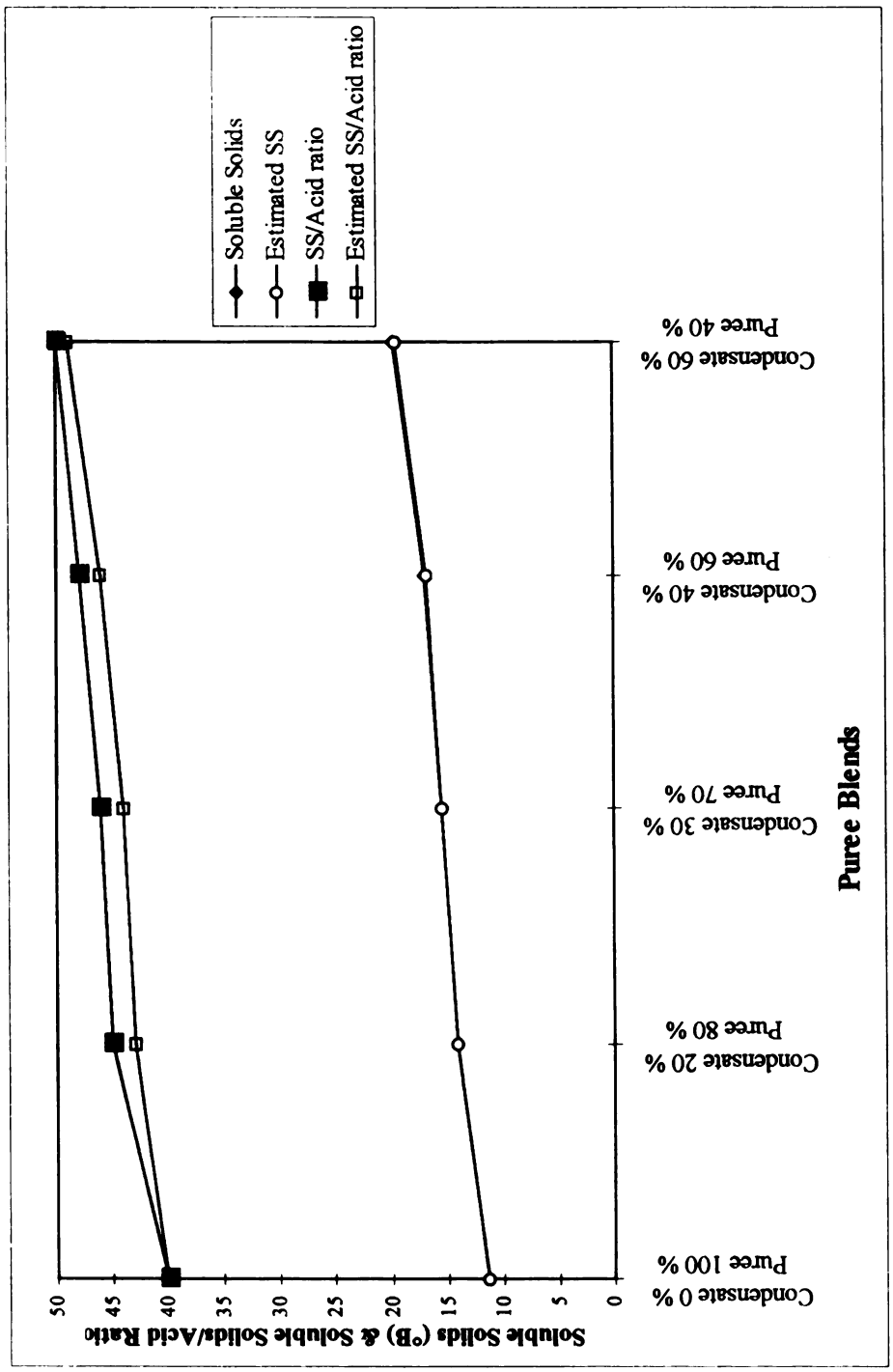


Figure 27 Actual vs. estimated values of soluble solids and soluble solids/acid ratio of low (LA; A-142) acid puree blends .(Soluble solids and estimated soluble solids are superimposed)

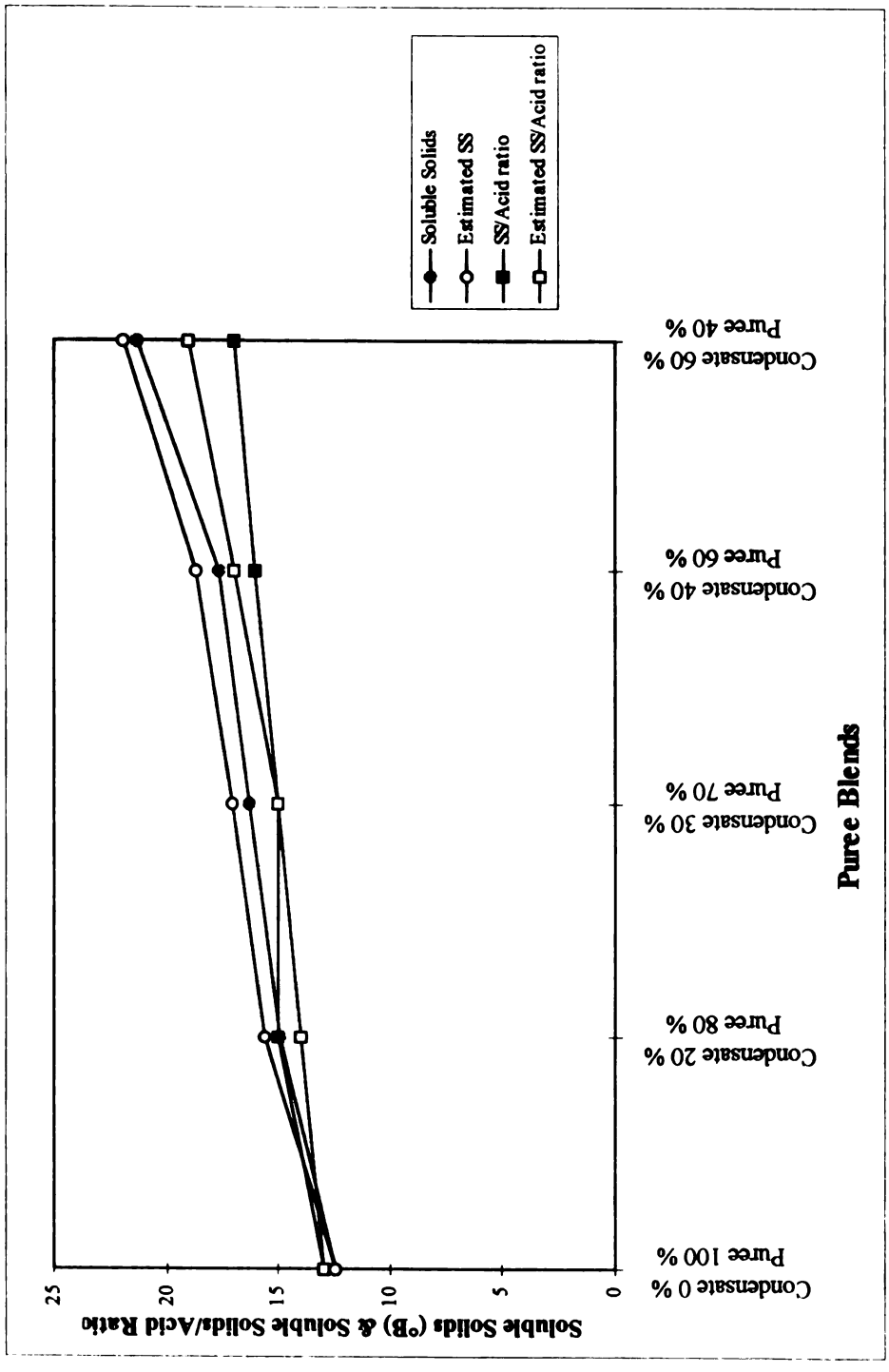


Figure 28 Actual vs. estimated values of soluble solids and soluble solids/acid ratio of high (HA; A-9) acid puree blends

SUMMARY AND CONCLUSIONS

The results of these studies indicate that the ultrafiltration process has increased the sugar content, phenolic content, and volatile compounds present in both low and high acid condensate fractions. It was shown that when condensate was added back to the original puree, the flavor enhanced condensates add value to the final puree.

The final puree blends of both low and high acid peaches increased in soluble solids, total acidity, and brix/acid ratio. The pH and lightness of the final puree blends decreased with an increase in condensate add back.

The amount and type of sugar present in the peach samples is an important aspect to the final sweetness of the puree. The major sugar found in all the peach samples were consistent with other studies. Other studies have shown that the major sugar in ripe peach fruit is sucrose (Brooks et al., 1993; Robertson et al., 1988). The sweetness of sucrose is greater than glucose, but less sweet than fructose.

The amount of sucrose present in low acid peach samples is greater than the amount present in high acid peach samples. The amount of sucrose present was most likely due to the maturity of the fruit. Brooks et al. (1993) concluded that the sucrose content increased significantly over stage of maturity. The length of time the fruit had to mature determined the amount of sucrose present. Low and high acid retentates increased

in total amount of sugar by nearly three-fold. The total volume of product decreased approximately ten times. This concentrated sugar retentate was used to increase the value of the final puree.

The high acid retentate had greater quantities of acid than the low acid retentate. The increase in acid in the retentates of both the low and high acid cultivars decreased the sweetness of the final product.

A three to four fold increase in phenolic content in the final retentates indicated the ultrafiltration process increased the phenolic content by about three-fold. Only trace amounts of phenols were present in the permeate.

APPENDICES

Appendix A

Supporting Data for Peach Fractions and Ultrafiltration Process Variables

Table A-1 Low (LA; A-142) and high (HA; A-9) acid permeate flux readings generated from microfiltration operated at 60-70 psi. at 100 °F

Time (min)	Low acid permeate flux ($L/m^2/hr$)	High acid permeate flux ($L/m^2/hr$)
0	14.21	12.49
5	10.33	9.9
10	9.04	8.18
20	8.61	6.89
30	7.32	6.89
40	7.32	5.6
50	6.89	6.46
60	6.46	4.74
75	6.46	4.74
90	6.03	4.74
105	5.60	4.74
120	5.60	4.74
135	5.60	4.74
150	5.60	4.74
165	5.60	4.31
195		4.31
225		4.31
Run 2		
0	13.8	12.06
5	10.8	9.04
10	9.0	6.46
30	6.9	5.6
60	6.0	4.74
90	5.6	4.31
120	5.6	4.31
180	5.2	4.31

Table A-2 Low (LA; A-142) and high (HA; A-9) acid retentate flux readings generated from nanofiltration operated at 350-400 psi at 100 °F

Time (min)	Low acid retentate flux ($L/m^2/hr$)	High acid retentate flux ($L/m^2/hr$)
3	36.7	27.20
5	13.6	29.92
9	6.8	13.60
13	20.7	20.40
17	34.0	28.56
25	13.6	29.92
Run # 2		
3	29.9	34.00
5	46.2	35.35
9	43.5	38.07
13	28.6	
Run # 3		
3	15.0	16.32
5	54.4	13.60
9	54.4	21.76
Run # 4		
3	43.5	
5	36.7	

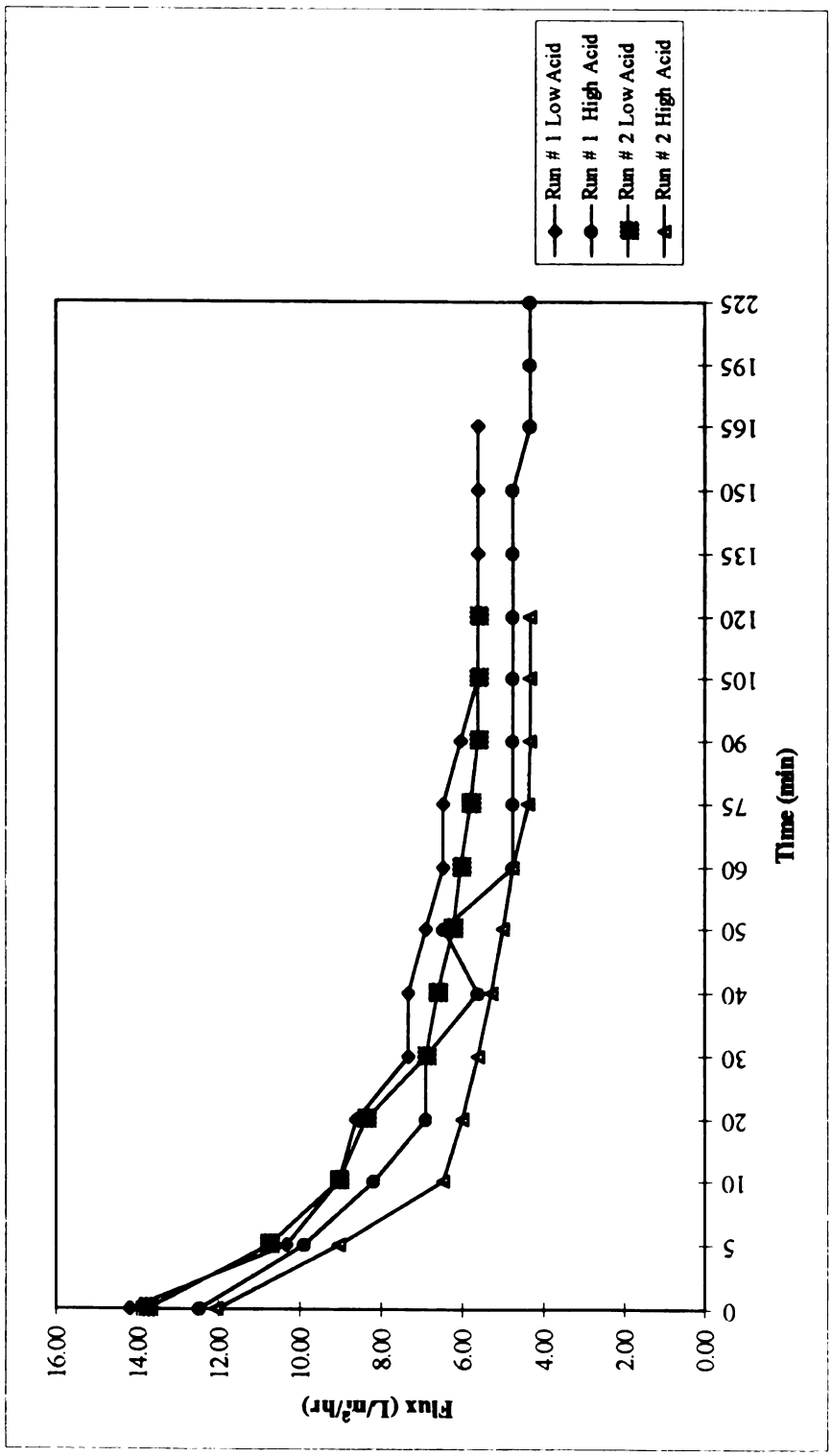


Figure A-1 Permeate flux readings produced by microfiltration of low (LA; A-142) and high (HA; A-9) acid peach condensate including run #1 and #2

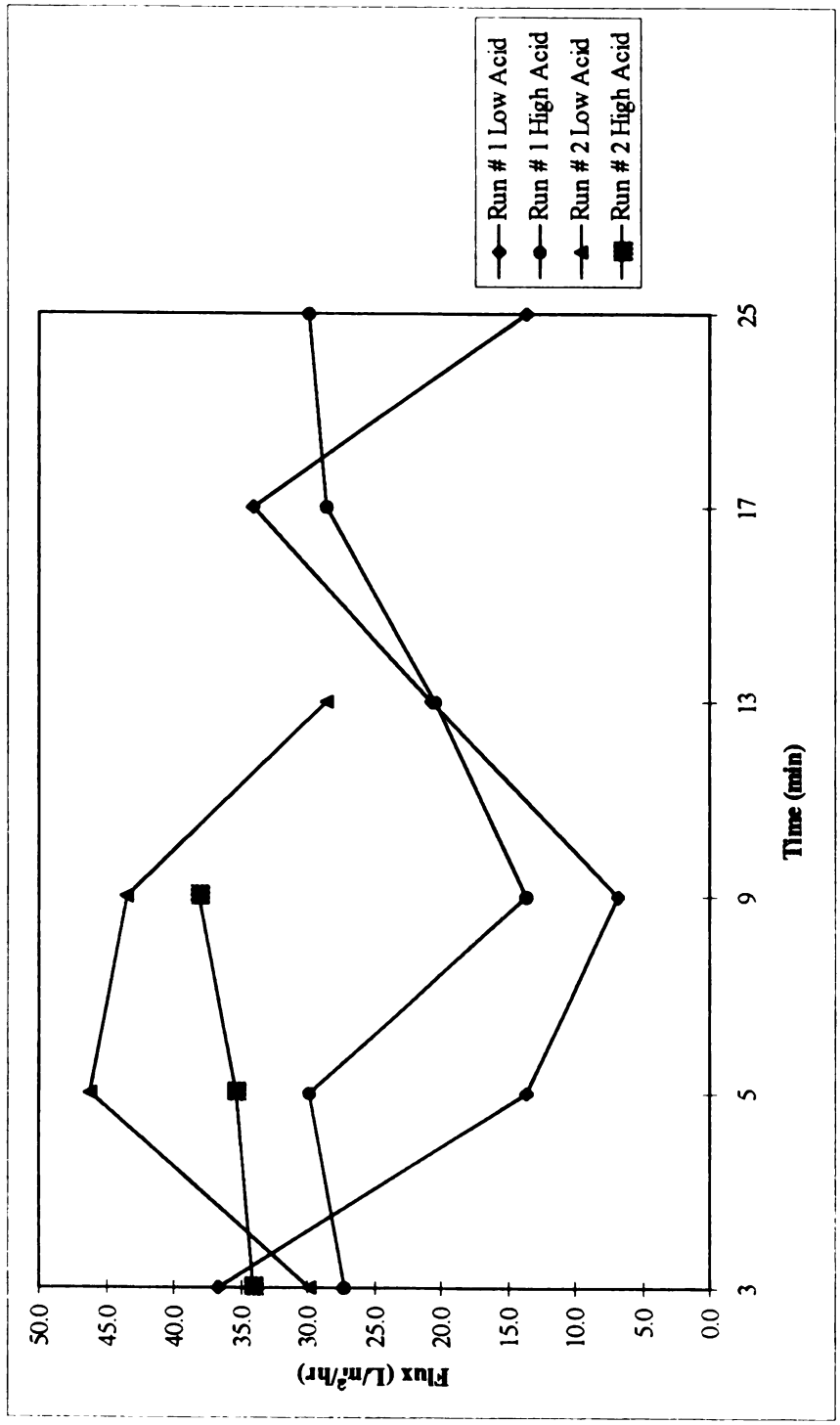


Figure A-2 Retentate flux readings produced by nanofiltration of low (LA; A-142) and high (HA; A-9) acid peach condensate including run #1 and #2

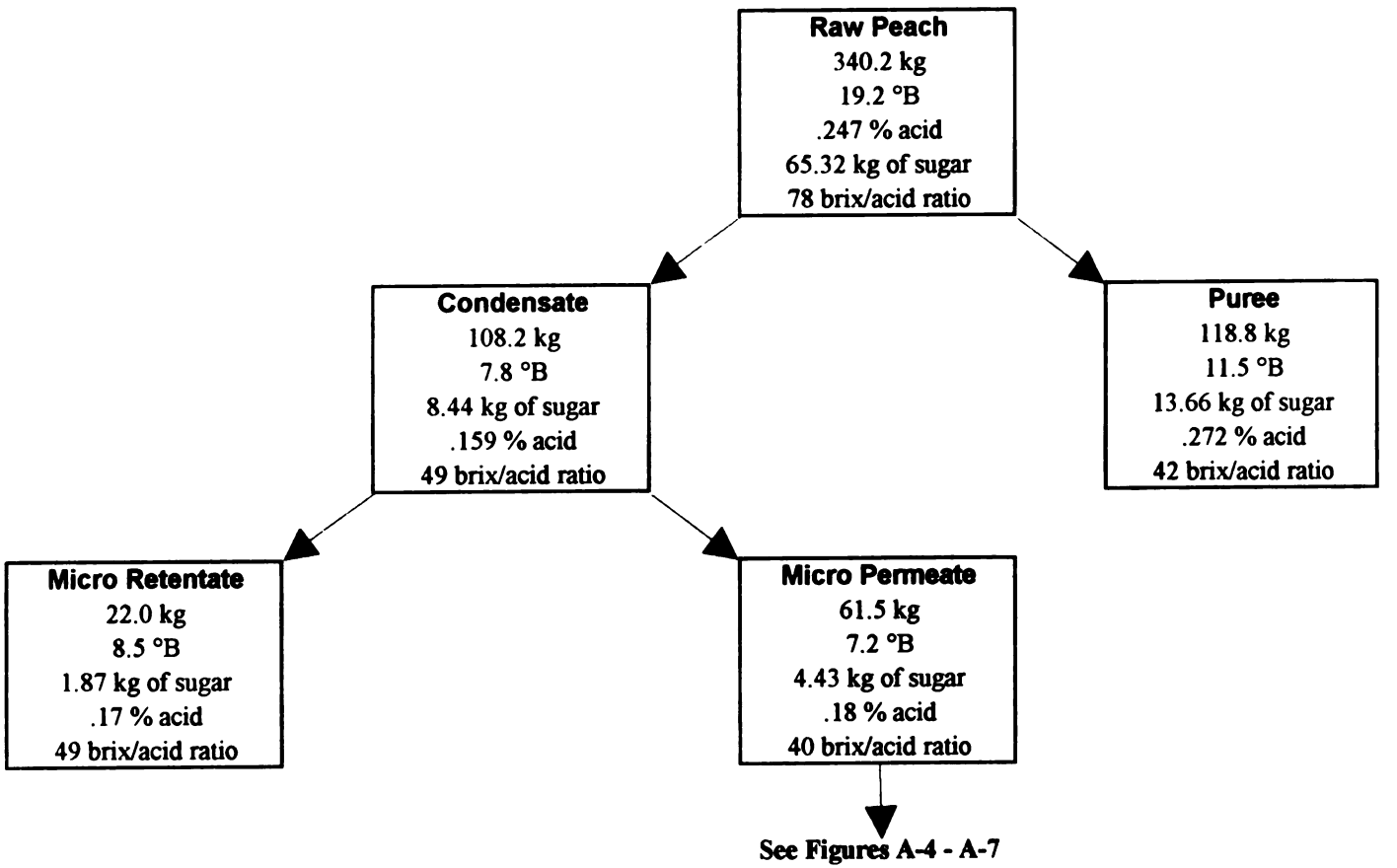


Figure A-3 Low (LA; A-142) acid mass balance of weight, total acidity, soluble solids, and brix/acid ratio of raw peach through microfiltration

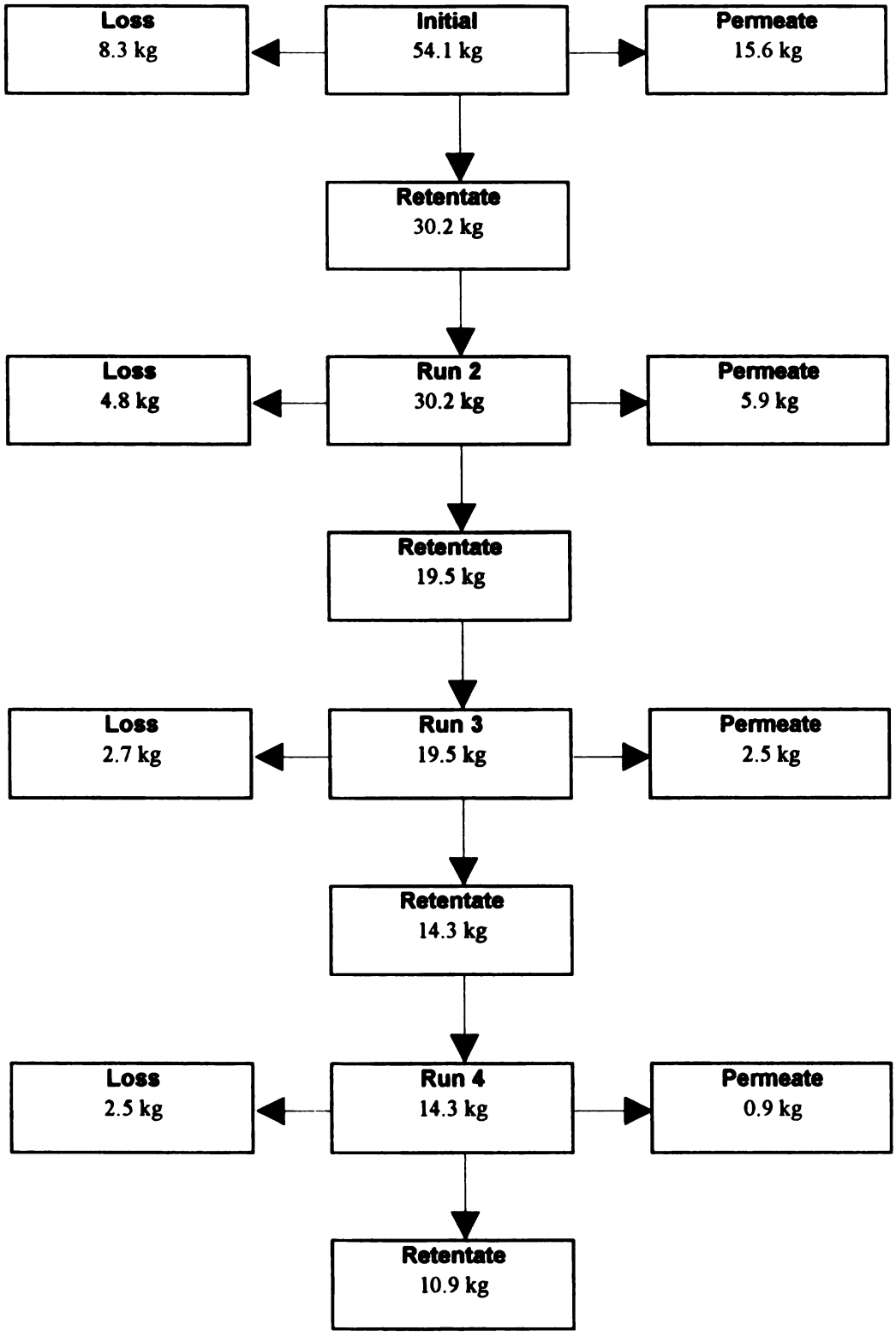


Figure A-4 Mass balance of weight of low (LA; A-142) acid peach condensate processed through nanofiltration membrane

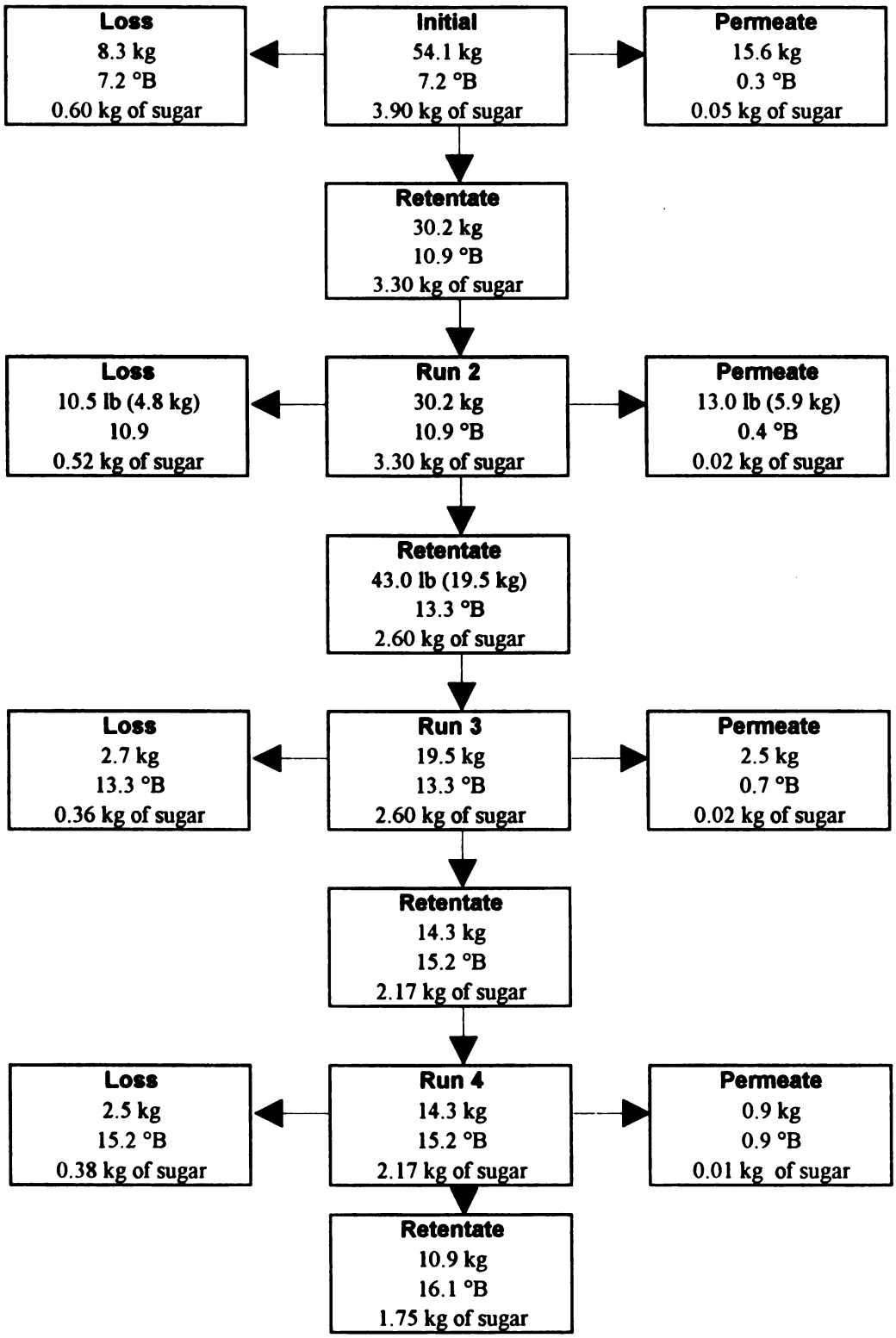


Figure A-5 Mass balance of soluble solids and sugar content of low (LA; A-142) acid peach condensate processed through nanofiltration membrane

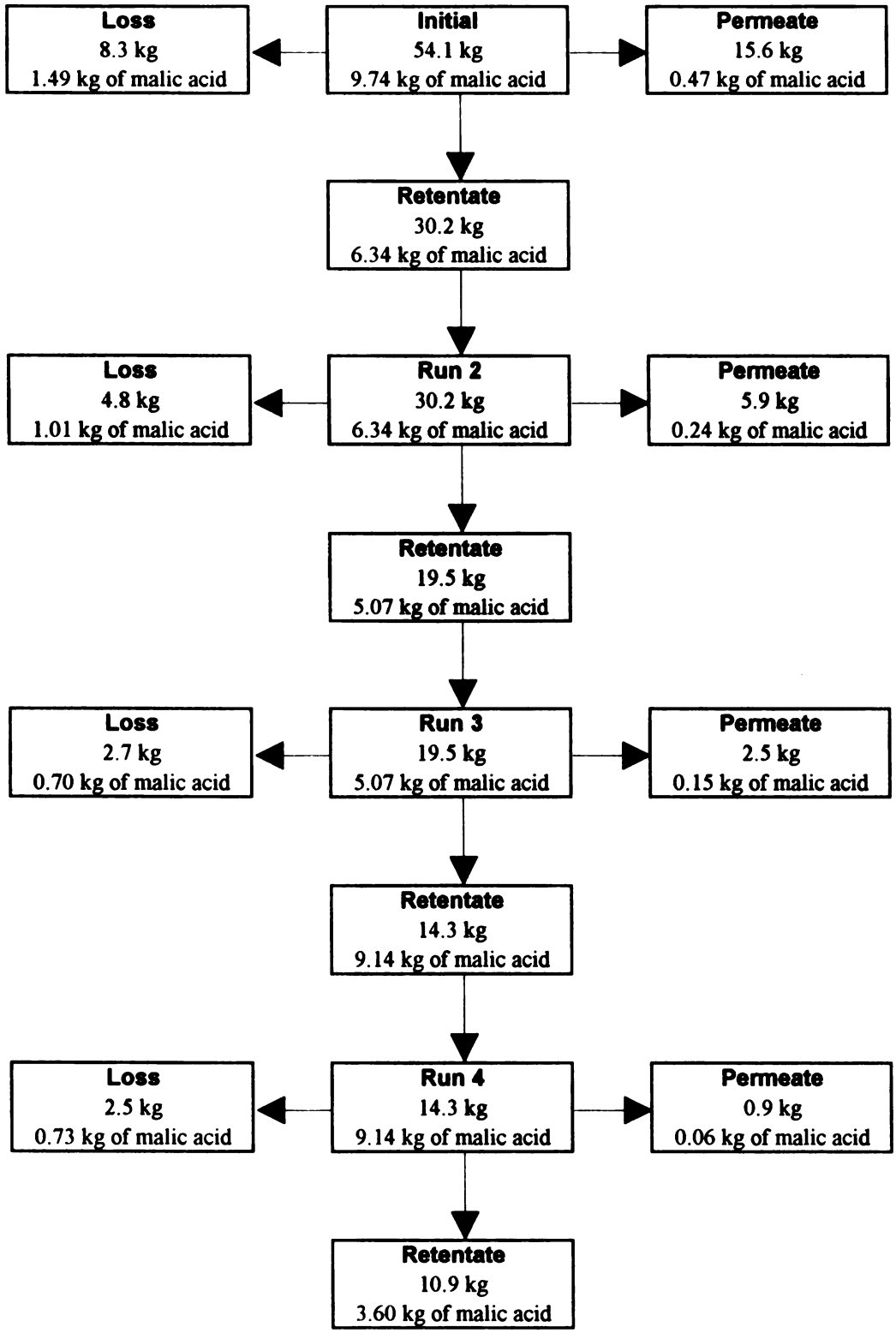


Figure A-6 Mass balance of acid (% malic) of low (LA; A-142) acid peach condensate processed through nanofiltration membrane

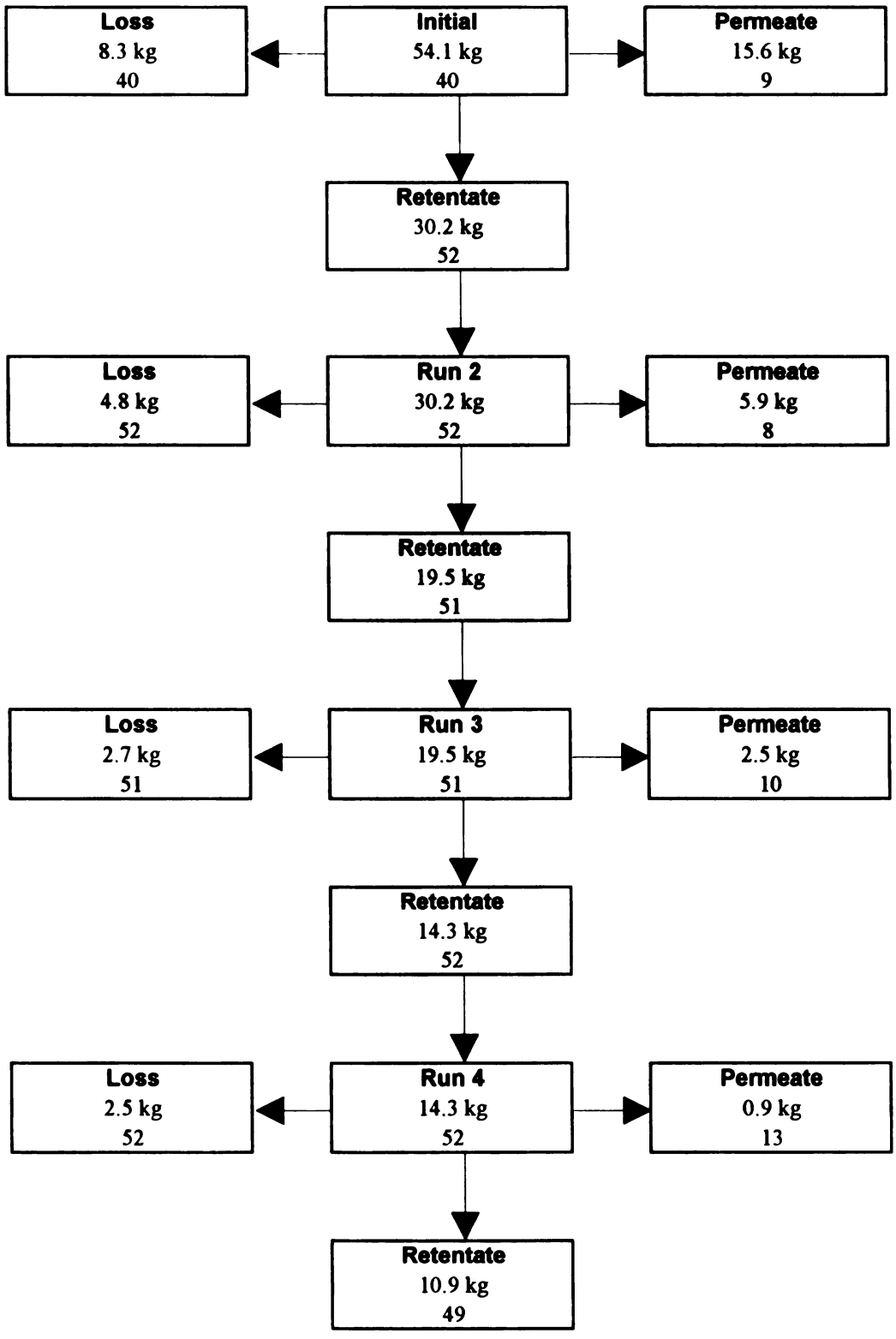


Figure A-7 Mass balance of brix/acid ratio of low (LA; A-142) acid peach condensate processed through nanofiltration membrane

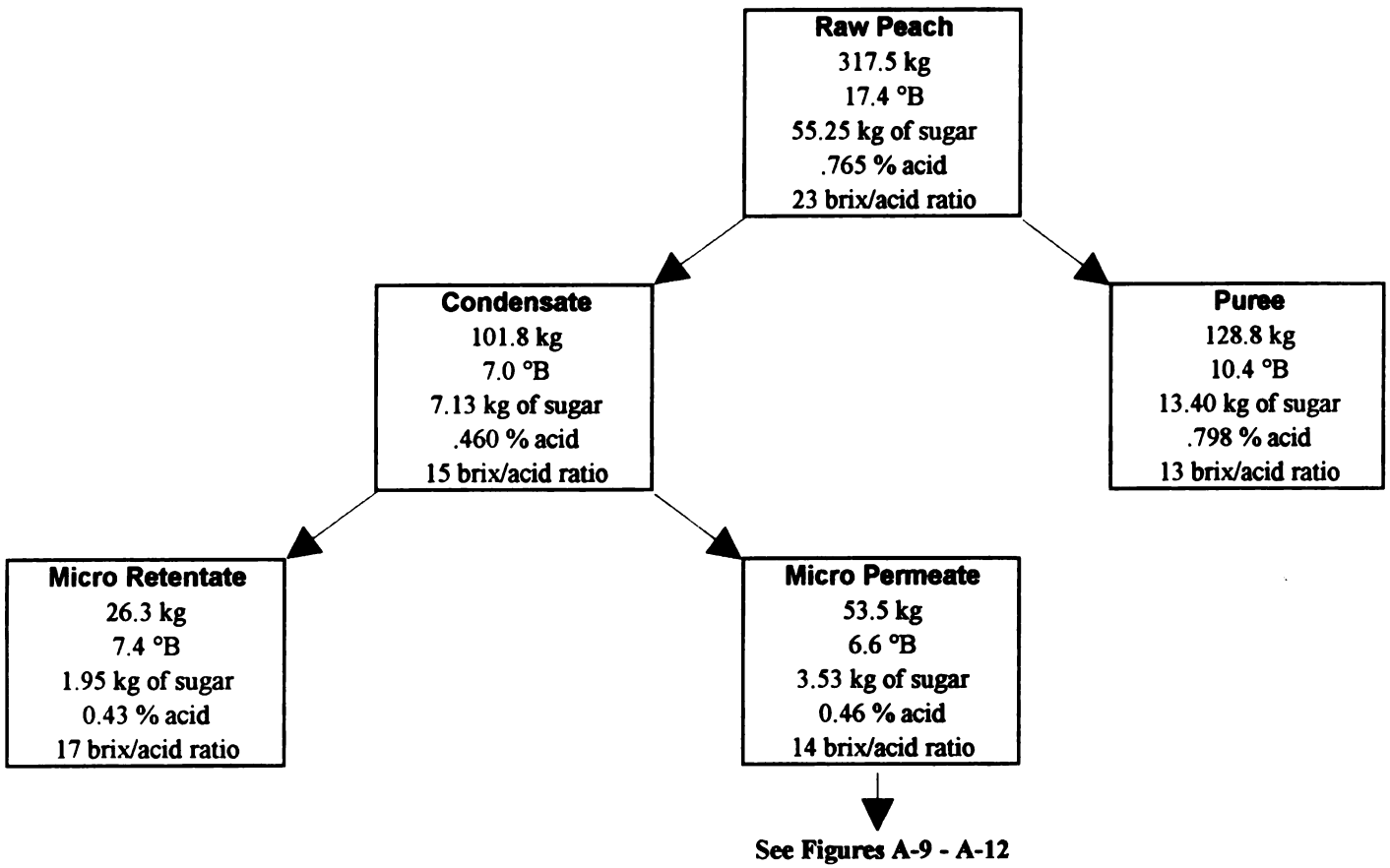


Figure A-8 High (HA; A -9) acid mass balance of weight, total acidity, soluble solids, and brix/acid ratio of raw peach through microfiltration

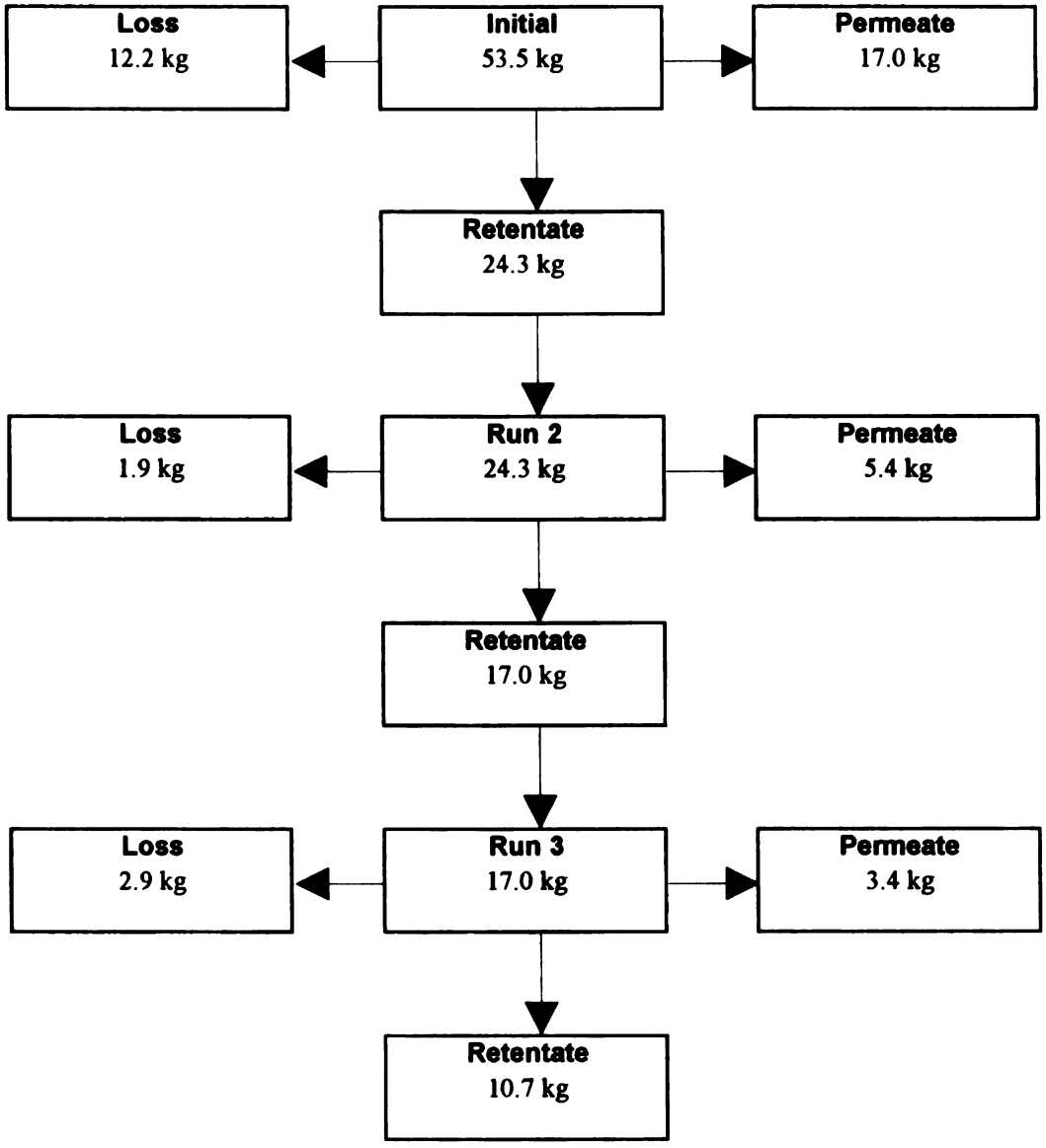


Figure A-9 Mass balance of weight of high (HA; A-9) acid peach condensate processed through nanofiltration membrane

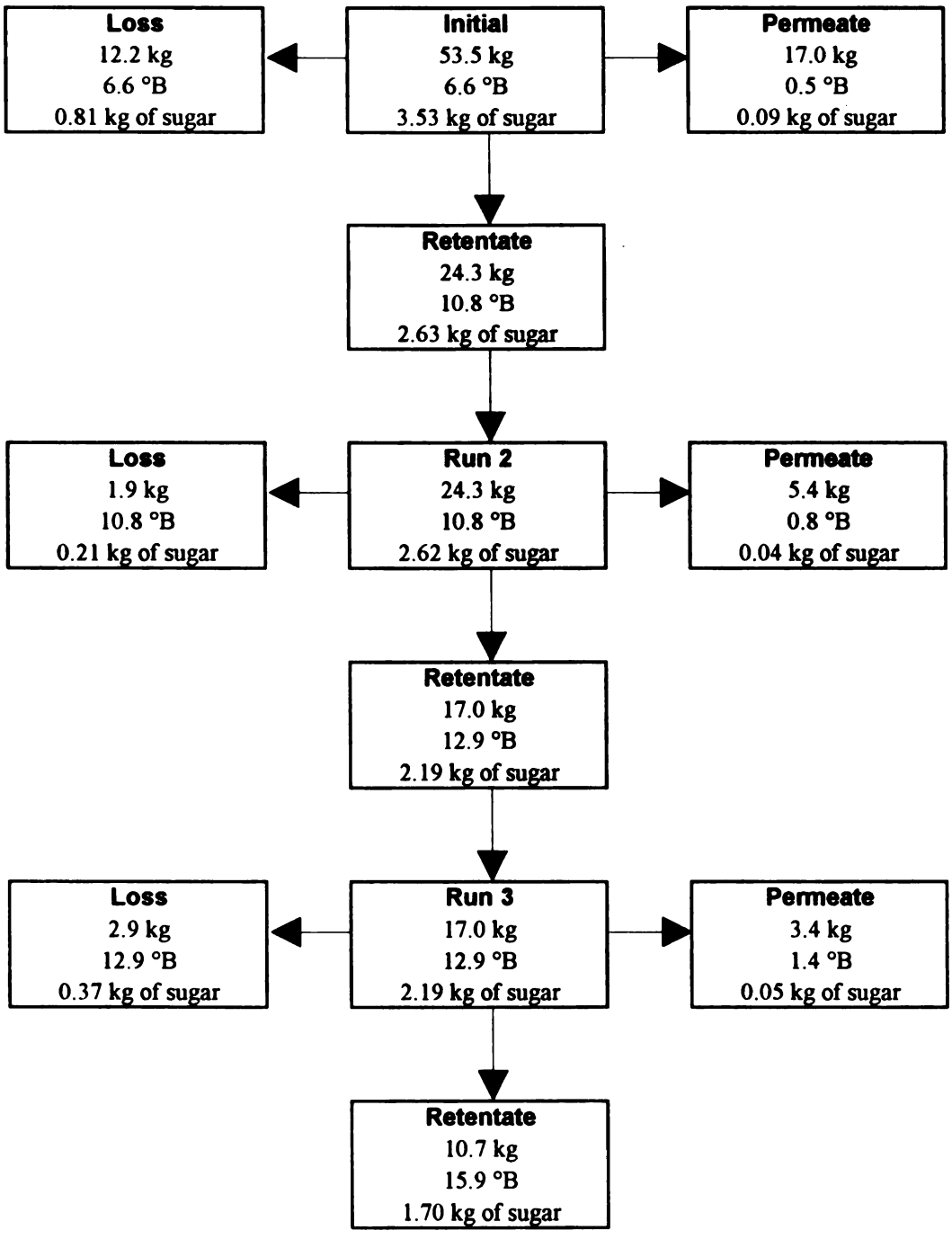


Figure A-10 Mass balance of soluble solids and sugar content of high (HA; A-9) acid peach condensate processed through nanofiltration membrane

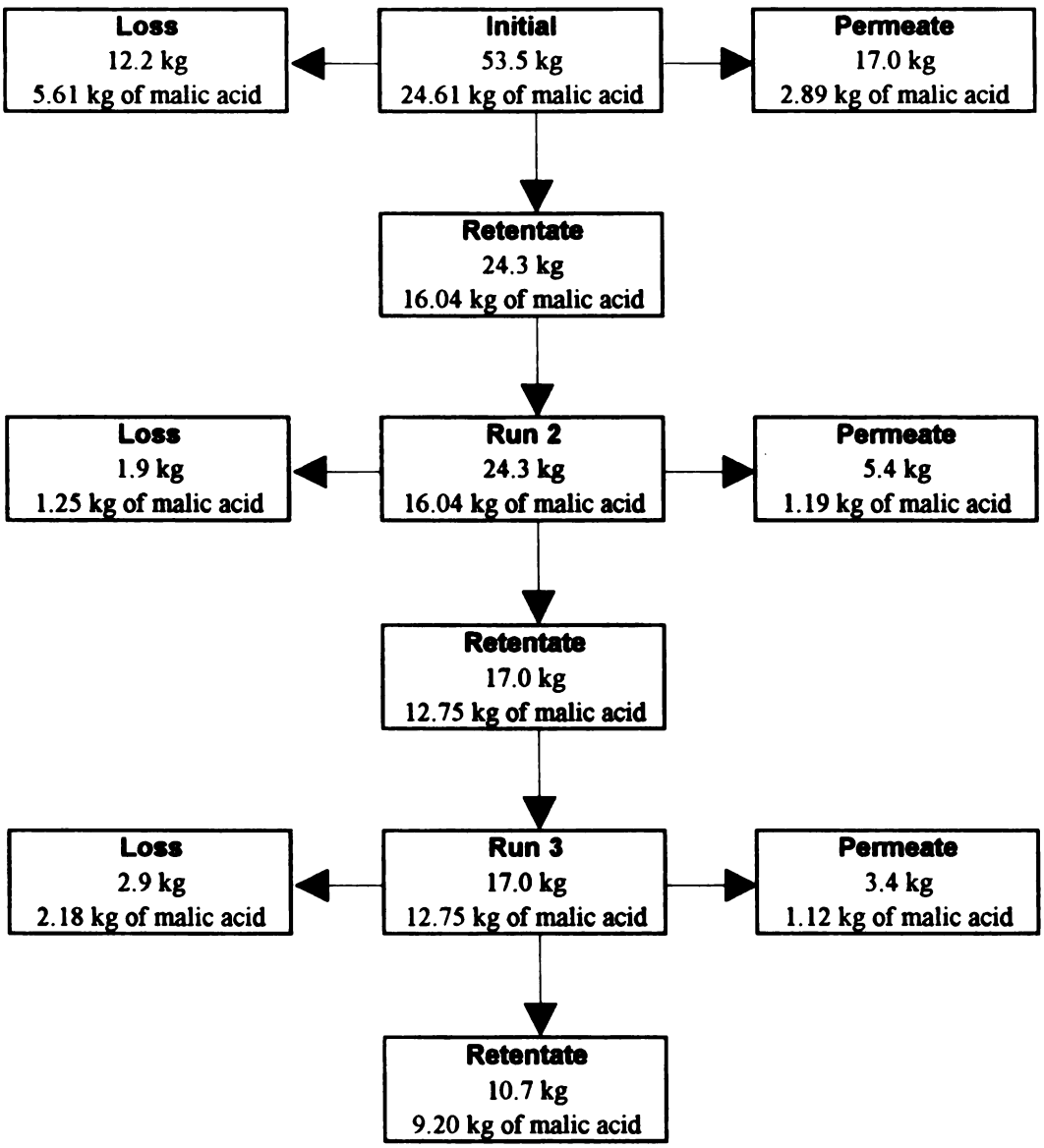


Figure A-11 Mass balance of acid (% malic) of high (HA; A-9) acid peach condensate processed through nanofiltration membrane

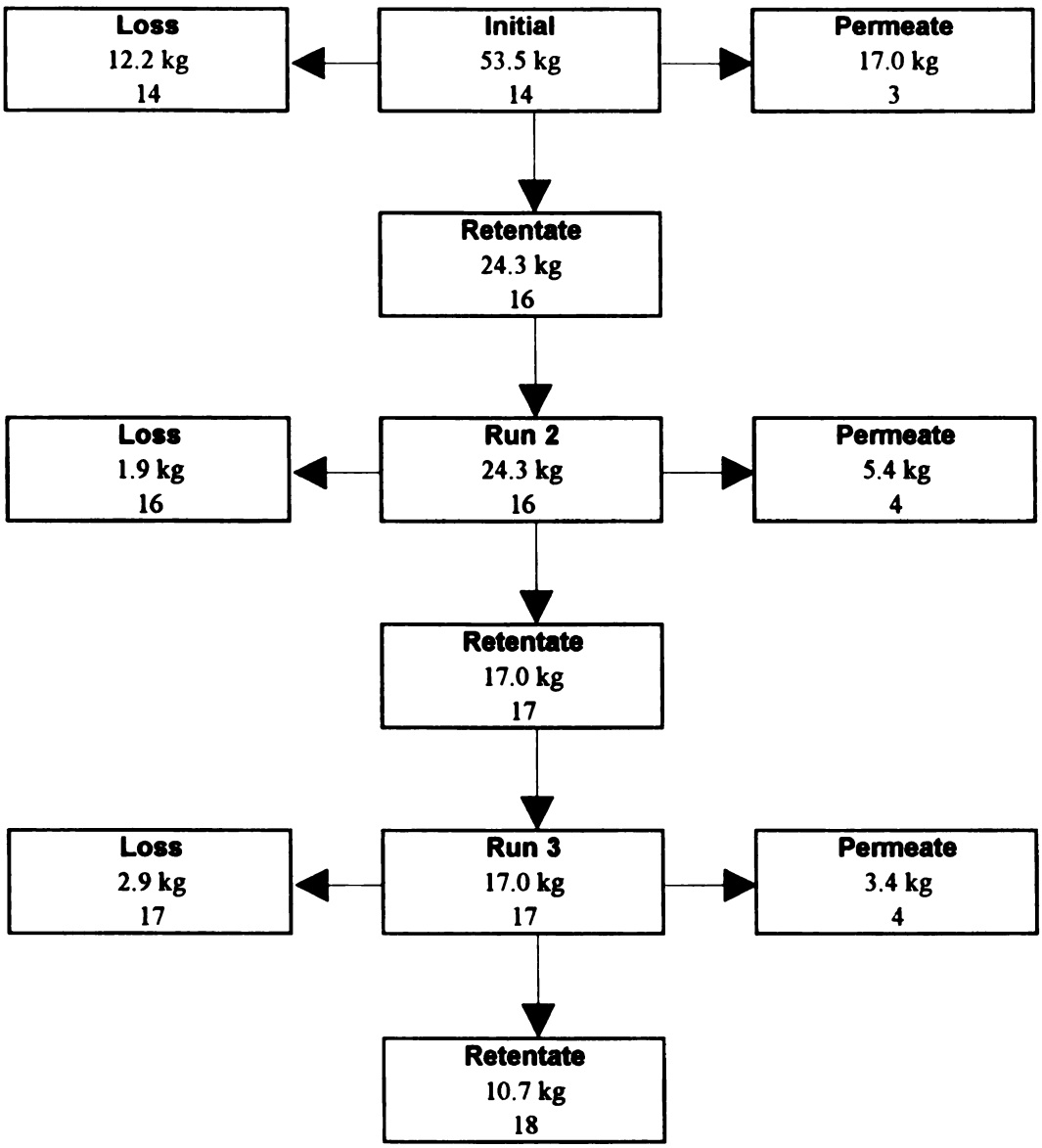


Figure A-12 Mass balance of brix/acid ratio of high (HA; A-9) acid peach condensate processed through nanofiltration membrane

Table A-3 High pressure liquid chromatography analyses of two samples indicate the total sugar content and individual levels of sugars present in low (LA; A-142) acid peach puree, condensate, and condensates generated from the ultrafiltration process

Sample	Sucrose %	Glucose %	Fructose %	Sorbitol %	Total %
LA Puree	**5.57**	**1.35**	**1.60**	**0.06**	**8.56**
Std Dev	0.52	0.06	0.15	0.01	0.74
LA Condensate	**3.84**	**0.77**	**0.87**	**0.03**	**5.51**
Std Dev	0.07	0.01	0.01	0.00	0.09
LA Micro Retentate	**4.44**	**0.84**	**1.04**	**0.04**	**6.35**
Std Dev	0.14	0.05	0.08	0.00	0.27
LA Micro Permeate	**4.40**	**0.83**	**0.98**	**0.04**	**6.25**
Std Dev	0.08	0.00	0.01	0.01	0.08
LA Retentate #1	**7.08**	**1.26**	**1.52**	**0.06**	**9.92**
Std Dev	0.12	0.00	0.01	0.00	0.13
LA Retentate #2	**8.48**	**1.53**	**1.80**	**0.07**	**11.88**
Std Dev	0.21	0.06	0.06	0.00	0.33
LA Retentate #3	**10.15**	**1.76**	**2.14**	**0.09**	**14.13**
Std Dev	0.36	0.06	0.04	0.01	0.35
LA Retentate #4	**10.83**	**1.88**	**2.24**	**0.09**	**15.03**
Std Dev	0.45	0.06	0.00	0.01	0.40
LA Permeate #1	**0.06**	**0.10**	**0.09**	**0.01**	**0.24**
Std Dev	0.01	0.02	0.02	0.01	0.06
LA Permeate #2	**0.07**	**0.12**	**0.14**	**0.01**	**0.34**
Std Dev	0.00	0.00	0.00	0.00	0.00
LA Permeate #3	**0.09**	**0.19**	**0.21**	**0.02**	**0.50**
Std Dev	0.01	0.01	0.00	0.01	0.01
LA Permeate #4	**0.10**	**0.26**	**0.28**	**0.02**	**0.66**
Std Dev	0.00	0.00	0.00	0.00	0.00

Table A-4 High pressure liquid chromatography analyses of two samples indicate the total sugar content and individual levels of sugars present in high (HA; A-9) acid peach puree, condensate, and condensates generated from the ultrafiltration process

Sample	Sucrose %	Glucose %	Fructose %	Sorbitol %	Total %
HA Puree	**3.20**	**1.72**	**1.74**	**0.07**	**6.72**
Std Dev	0.11	0.00	0.02	0.01	0.14
HA Condensate	**3.52**	**0.94**	**1.07**	**0.06**	**5.59**
Std Dev	0.09	0.03	0.06	0.00	0.12
HA Micro Retentate	**2.79**	**0.64**	**0.80**	**0.04**	**4.27**
Std Dev	0.00	0.01	0.01	0.00	0.03
HA Micro Permeate	**3.52**	**0.91**	**1.11**	**0.06**	**5.59**
Std Dev	0.15	0.02	0.02	0.00	0.19
HA Retentate #1	**5.92**	**1.52**	**1.81**	**0.10**	**9.34**
Std Dev	0.05	0.01	0.03	0.01	0.00
HA Retentate #2	**7.18**	**1.99**	**2.18**	**0.12**	**11.47**
Std Dev	0.04	0.01	0.06	0.00	0.12
HA Retentate #3	**9.31**	**2.84**	**2.68**	**0.15**	**14.98**
Std Dev	0.16	0.11	0.07	0.01	0.19
HA Permeate #1	**0.05**	**0.28**	**0.12**	**0.01**	**0.46**
Std Dev	0.05	0.01	0.00	0.00	0.04
HA Permeate #2	**0.09**	**0.34**	**0.18**	**0.02**	**0.62**
Std Dev	0.01	0.01	0.01	0.00	0.03
HA Permeate #3	**0.11**	**0.50**	**0.35**	**0.03**	**0.98**
Std Dev	0.00	0.02	0.01	0.00	0.03

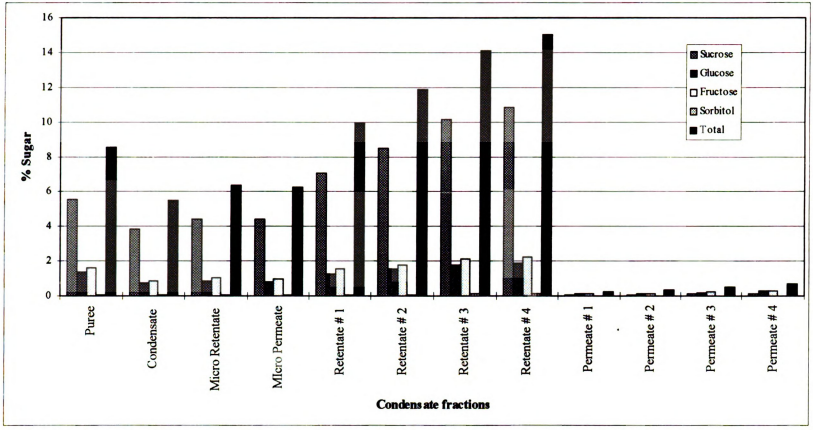


Figure A-13 Low (LA; A-142) acid peach puree, condensate, and condensates generated from the ultrafiltration process illustrating total sugar content and each individual level of sucrose, glucose, fructose, and sorbitol levels

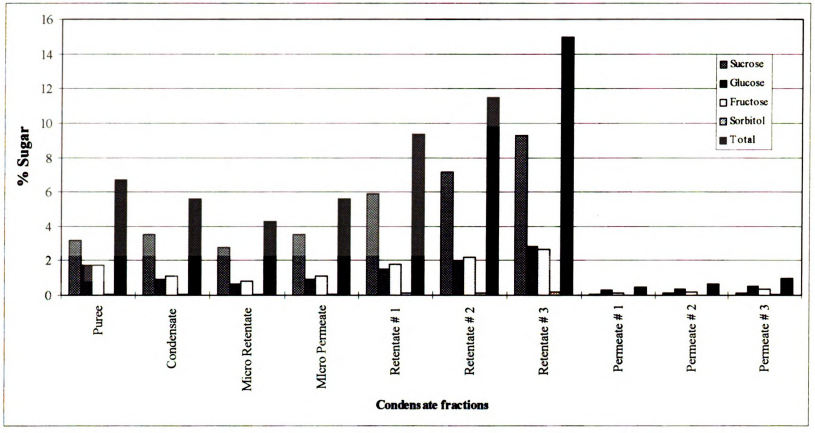


Figure A-14 High (HA; A-9) acid peach puree, condensate, and condensates generated from the ultrafiltration process illustrating total sugar content and each individual level of sucrose, glucose, fructose, and sorbitol levels

Appendix B

The Effect of Pressure and Recycling of Commercial Peach Condensate on the Ultrafiltration System

Peach condensate was collected and frozen on September 11, 1996 at Gerber Products Company in Fremont, Michigan. The frozen condensate was transported to the Food Processing Center, Michigan State University. The peach condensate was thawed and used to evaluate the ultrafiltration system and study the effects of recycling the condensate.

Results and Discussion

Figures B1-4 illustrate the mass balance of recycling condensate at 350 psi by weight, soluble solids and sugar content, acid, and brix/acid ratio, respectively. Figures B5-8 illustrate the mass balance of nanofiltration at 450 psi by weight, soluble solids and sugar content, acid, and brix/acid ratio, receptively. Figures B9-12 illustrate the mass balance of recycling condensate at 550 psi by weight, soluble solids and sugar content, acid, and brix/acid ratio, respectively. The effect of brix/acid ratio and soluble solids on the ultrafiltration system at three different pressures is presented in figure B-13.

Both the cultivar and maturity of fruit at the time of harvest directly effected the sweetness of the puree and condensate. The mixture of puree and condensate determined the sweetness of the final puree. The alteration of condensate to increase the soluble solids and brix/acid ratio creates a more desirable final puree.

When seasonal conditions are not optimal for the growth of peaches, the resulting fruit produced is undesirable. The ultrafiltration system can be used to increase the sweetness of the condensate and produce a final product which will be more desirable to the consumer.

Conclusion

The ultrafiltration system increased the brix/acid ratio and soluble solids after each consecutive cycle at 350/450/550 psi. The amount of acid present in the retentate was decreased after each cycle. Thus, the final condensate can be added back to the final puree to produce a more desirable product.

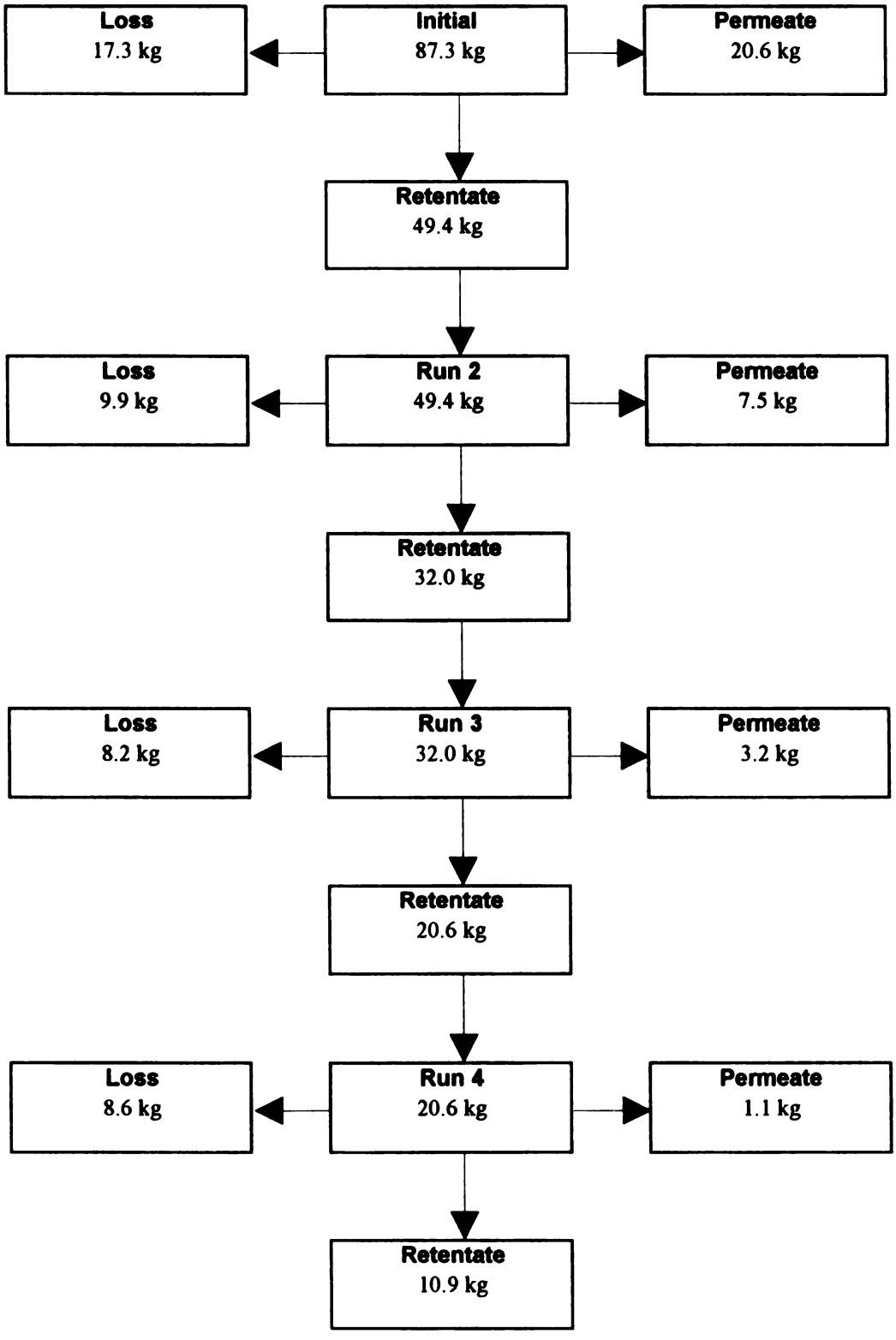


Figure B-1 Mass balance for weight distribution of nanofiltration process at 350 psi using peach condensate generated from a commercial processor

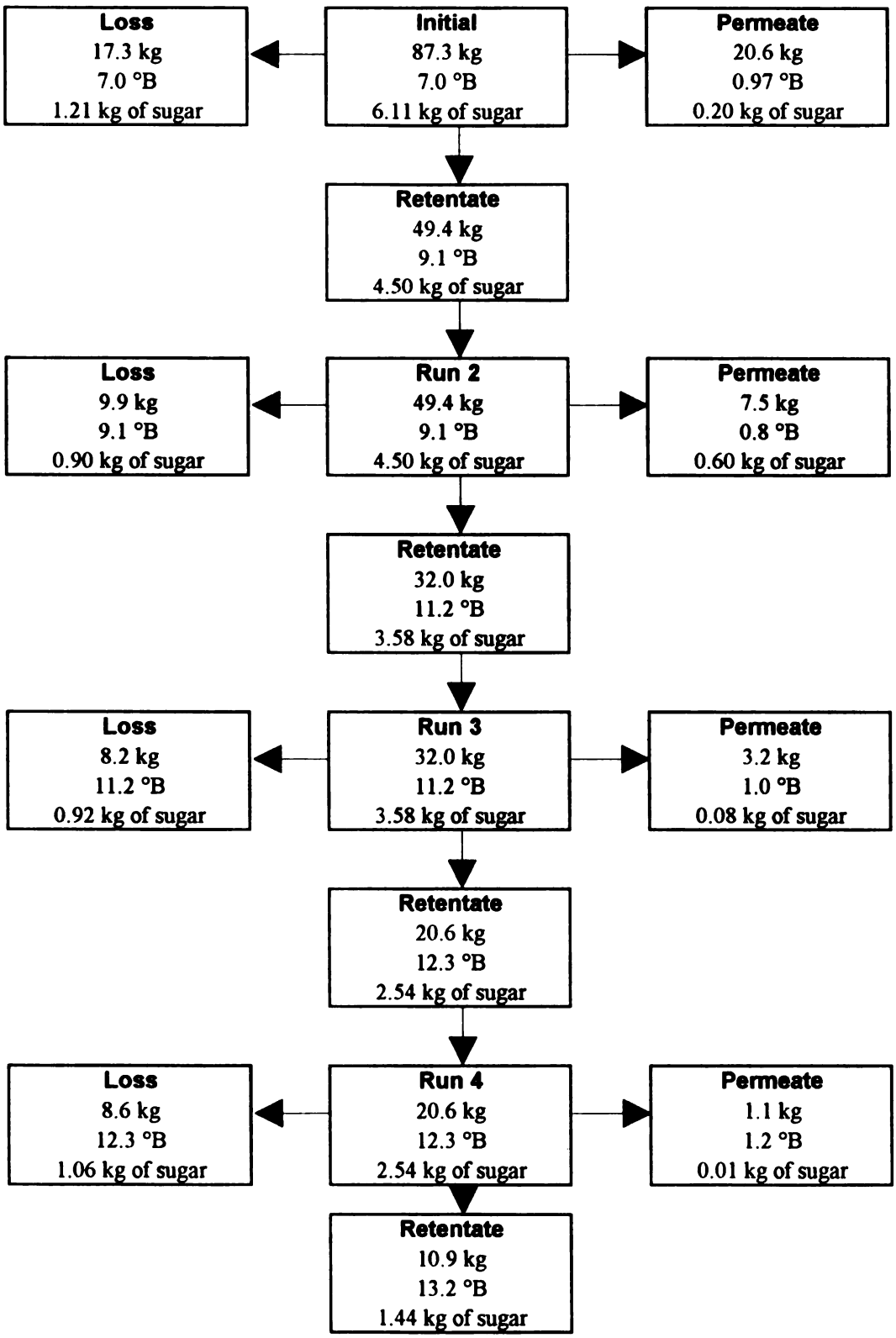


Figure B-2 Mass balance for soluble solids and sugar content distribution of nanofiltration process at 350 psi using peach condensate generated from a commercial processor

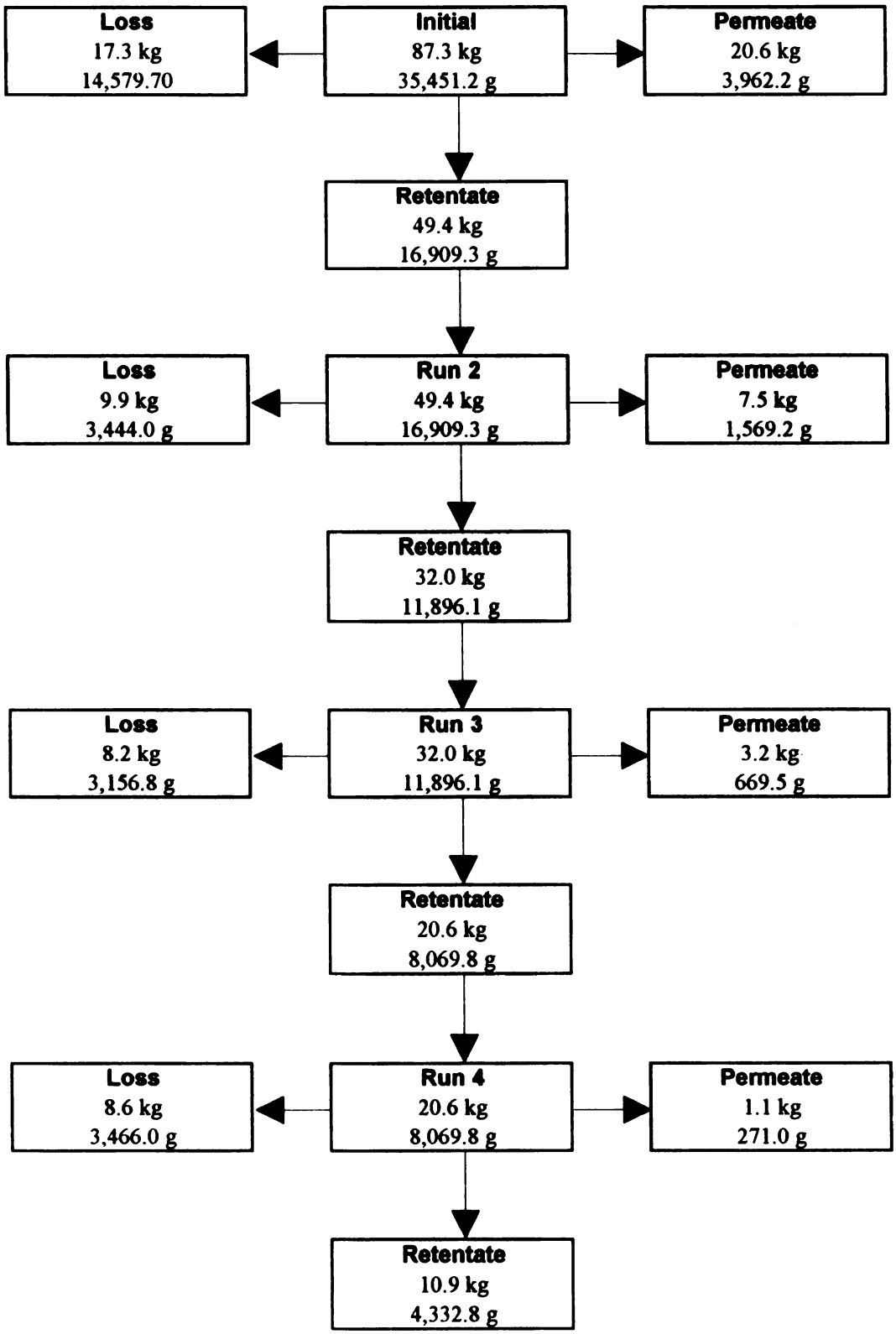


Figure B-3 Mass balance for acid (% malic) distribution of nanofiltration process at 350 psi using peach condensate generated from a commercial processor

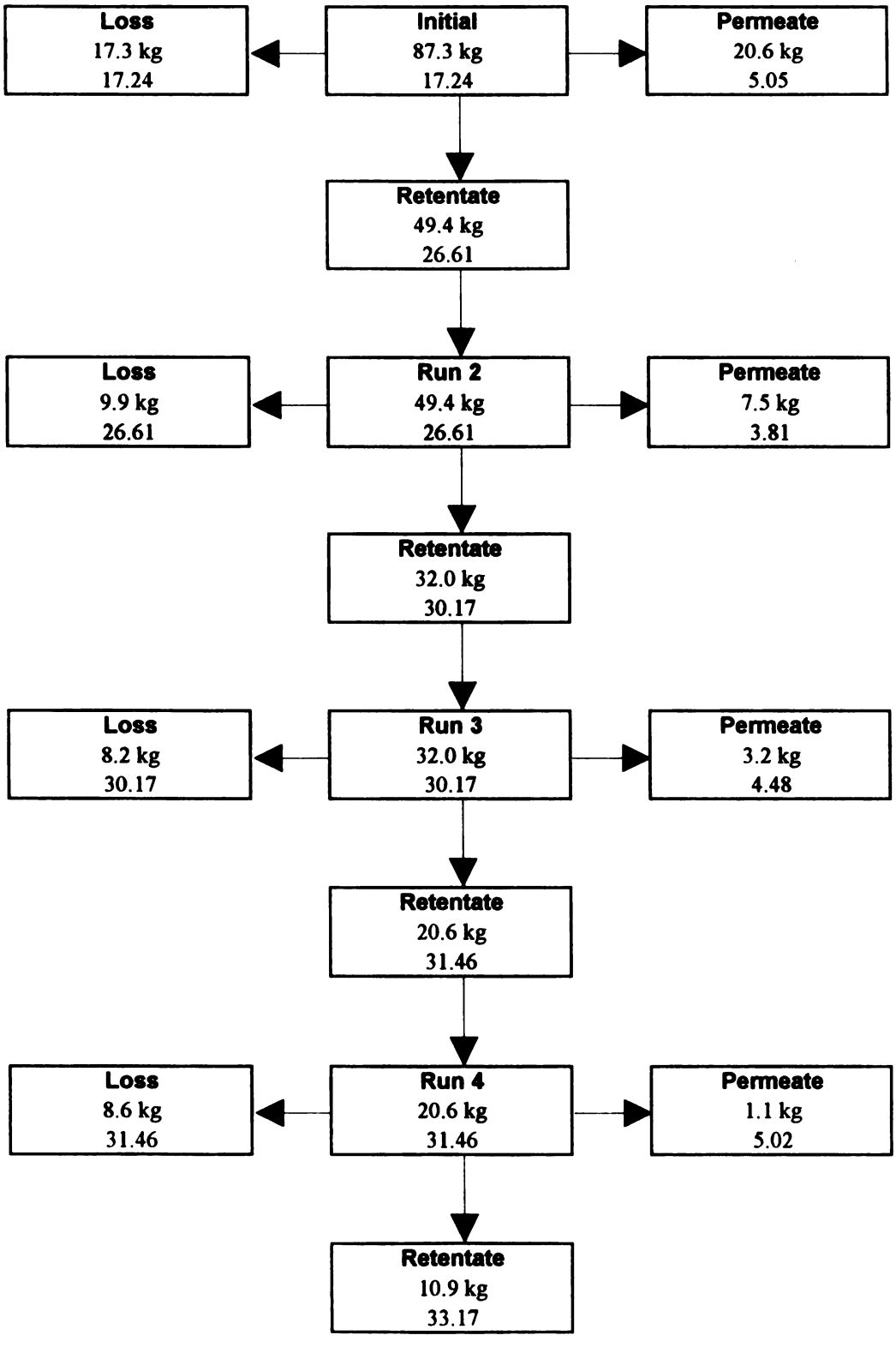


Figure B-4 Mass balance for brix/acid ratio distribution of nanofiltration process at 350 psi using peach condensate generated from a commercial processor

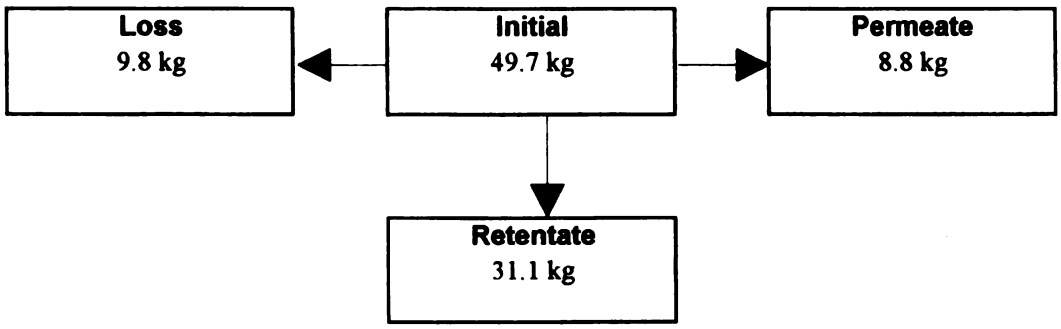


Figure B-5 Mass balance for weight distribution of nanofiltration process at 450 psi using peach condensate generated from a commercial processor

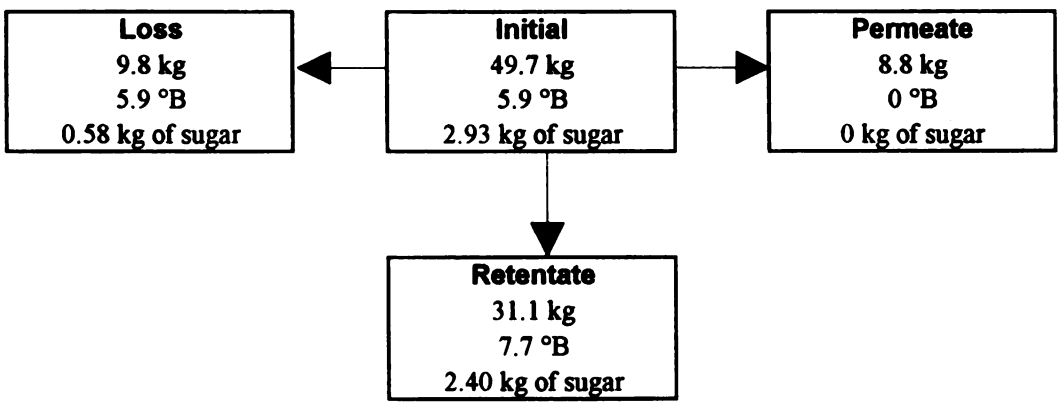


Figure B-6 Mass balance for soluble solids and sugar content distribution of nanofiltration process at 450 psi using peach condensate generated from a commercial processor

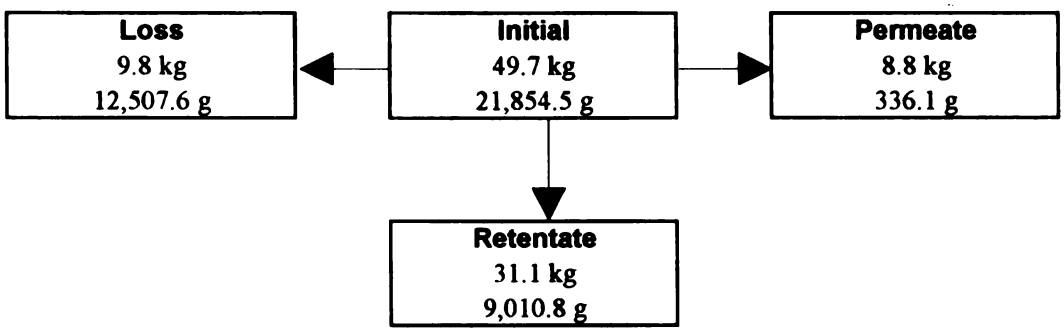


Figure B-7 Mass balance for acid (% malic) distribution of nanofiltration process at 450 psi using peach condensate generated from a commercial processor

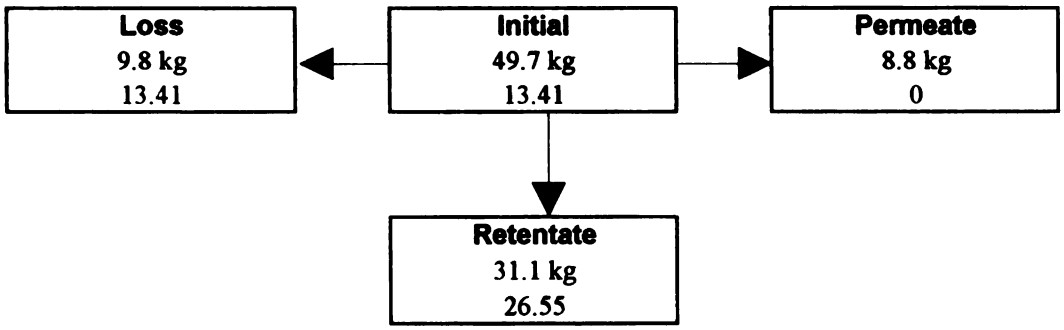


Figure B-8 Mass balance for brix/acid ratio distribution of nanofiltration process at 450 psi using peach condensate generated from a commercial processor

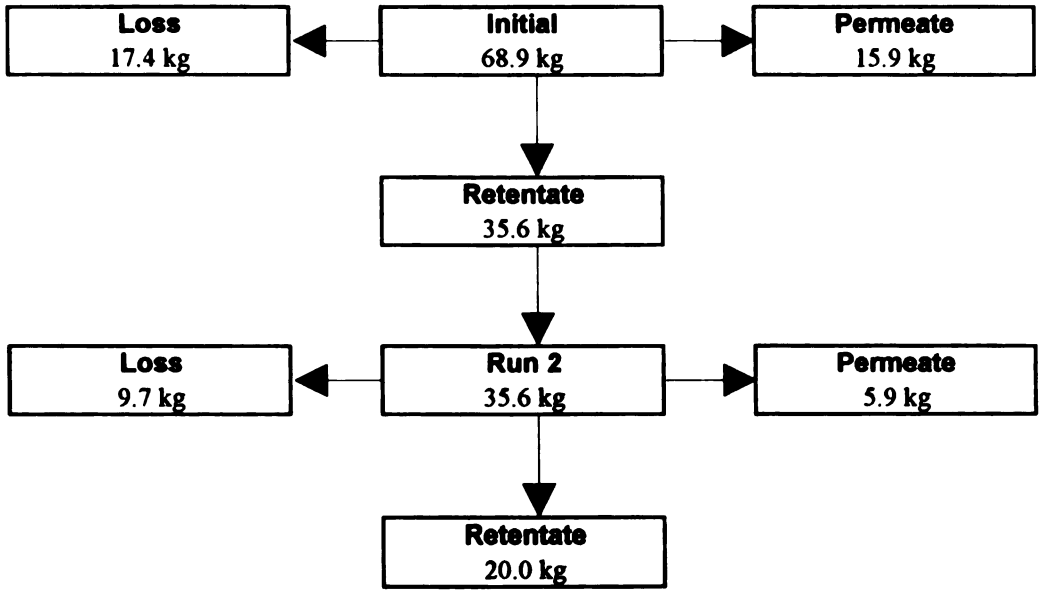


Figure B-9 Mass balance for weight distribution of nanofiltration process at 550 psi using peach condensate generated from a commercial processor

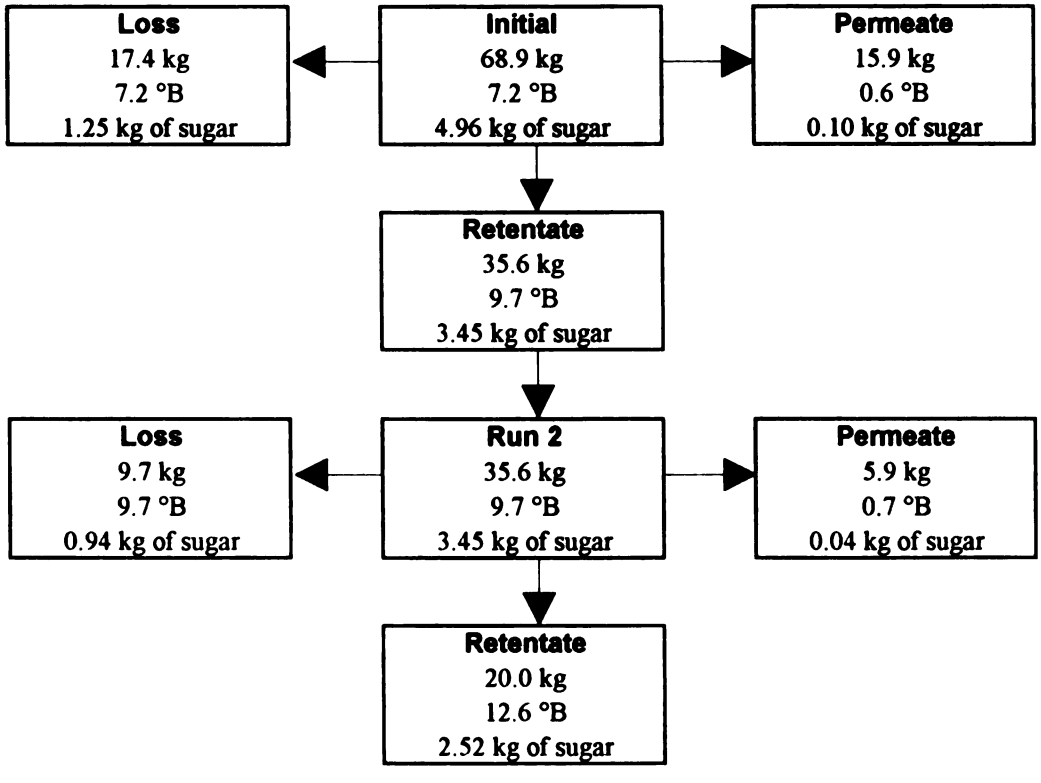


Figure B-10 Mass balance for soluble solids and sugar content distribution of nanofiltration process at 550 psi using peach condensate generated from a commercial processor

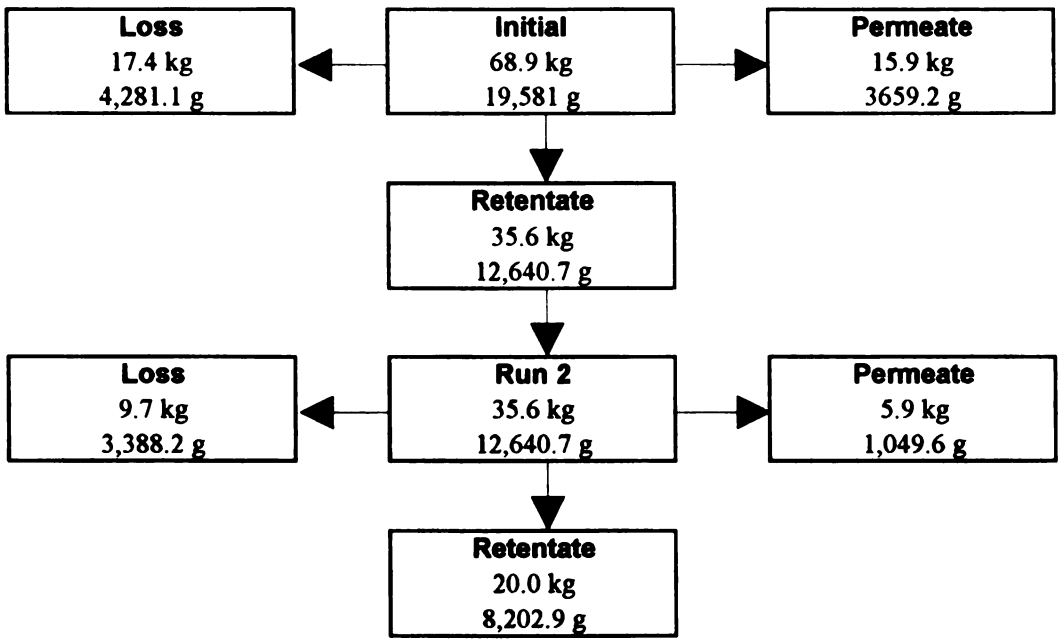


Figure B-11 Mass balance for acid (% malic) distribution of nanofiltration process at 550 psi using peach condensate generated from a commercial processor

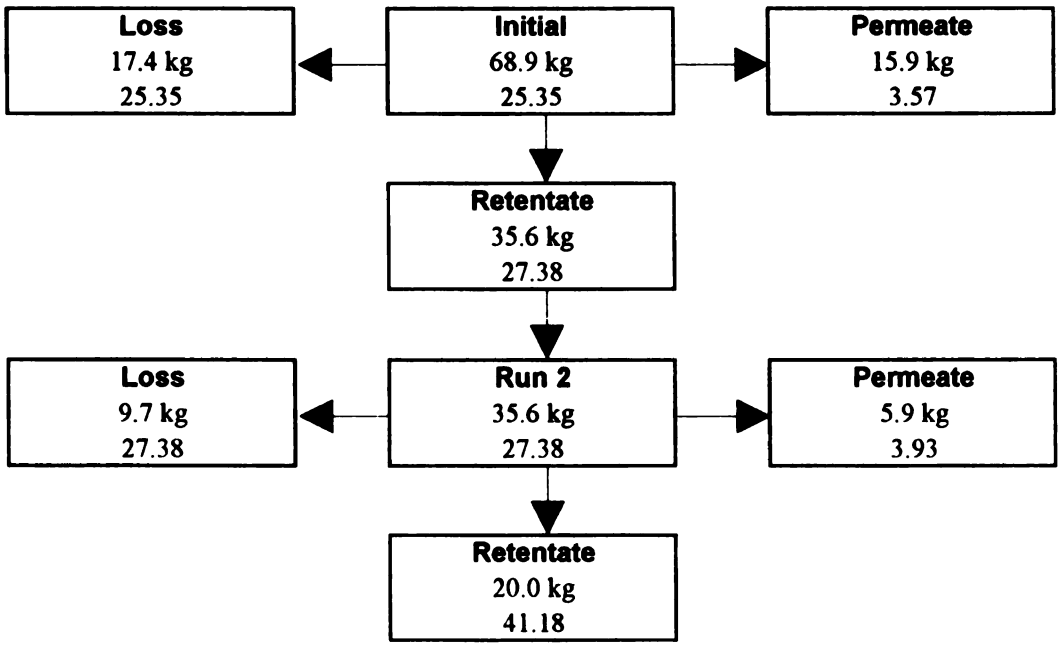


Figure B-12 Mass balance for brix/acid ratio distribution of nanofiltration process at 550 psi using peach condensate generated from a commercial processor

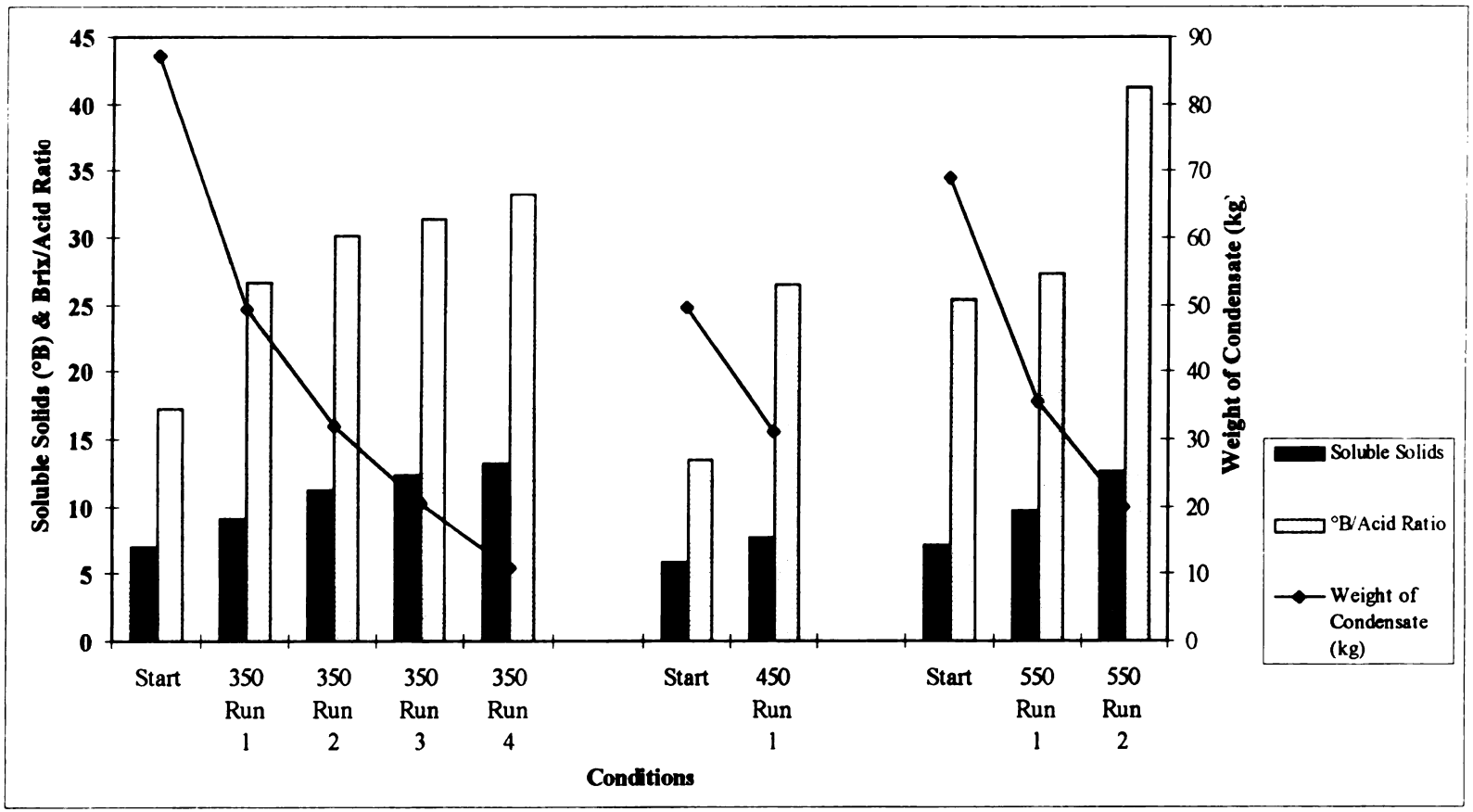


Figure B-13 Soluble solids, brix/acid ratio, and weight of condensate produced at 350/450/550 psi after recycling the peach condensate from a commercial processor through the nanofiltration process

Appendix C

A Qualitative Analysis of Pesticides on Low Acid (Arkansas- 142) Peach Puree, Condensate, and Filtrates Generated from the Ultrafiltration System

Peaches were processed at Michigan State University, Food Processing Center on September 12, 1996. After steam cooking, the puree and condensate were immediately frozen. The condensate was later thawed and used to evaluate the ultrafiltration system.

Materials and Methods

Four low acid peach samples were used to evaluate the pesticide residues. Samples were prepared for pesticide study using an ethyl acetate extraction method. Fifty grams of peach sample was weighed out into a 250 ml fleaker. Then 200 ml of ethyl acetate was added and mixed thoroughly. The mixture was held overnight to obtain separation. Once two layers had formed, the top layer was carefully poured into a tube. The tube was then placed into a Zymark Turbo Vap II at 50 °C until it was concentrated to 0.5 ml. The tube was placed under the hood and allowed to cool. The liquid was pipetted out of the tube and placed into a B-D cc syringe and filtered through a Gelman Nylon Acrodisc 0.45 *u*m filter. Then 0.5 ml of ethyl acetate was used to rinse the tube, syringe, and filter. The filtrate and wash was placed into a small vial and capped with a septum cap.

A standard sample was prepared for pesticides containing the following: 2 ppm Iprodine, 1.948 ppm Fenbuconizole, 2.392 ppm Permethin, 1.966 ppm Captan, 7.24 ppm Propiconozal, 2.08 ppm Guthion, 2.72 ppm Phosmet, 2.14 ppm Methyl Parathin.

A gas chromatograph and mass spectrometer were used to analyze the pesticides found in the peach samples. The equipment used was: a Varian 3400 Gas Chromatograph, a Varian Saturn II Mass Spectrometer with methane chemical ionization and electron impact ionization, a DB-608, film thickness 0.50 *u*m, 30 m x .25 mm Column, a Varian 8100 Autosampler, and a Saturn computer program. The autosampler injected 1.0 *u*l of sample into the system and ran for 20 minutes. The column was purged with pure methane gas to act as a buffer.

Results and Discussion

The peach trees were sprayed with a variety of pesticides to ensure a good yield of fruit in the fall. Pesticides used on the peach trees included: Captan, Thiodan, Guthion, Indar, Syliit, Imidan, Orbit, Ambush, Hamlin BBG 5, and Rovral.

A gas chromatograph standard was prepared to compare the results of pesticides present in the peach samples. The standard included: Iprodine, Fenbuconizole, Permethin, Propiconozal, Guthion, Phosmet, and Methyl Parathin.

The four peach samples evaluated included puree, condensate, retentate, and permeate. Figure C-1 illustrates the detection of Captan on the gas chromatogram of the peach puree sample. Figure C-2 illustrates the detection of Captan on the gas chromatogram of the condensate sample. Figure C-3 illustrates the detection of Captan

on the gas chromatogram of retentate sample. Figure C-4 illustrates the detection of Captan on the gas chromatogram of the permeate sample.

Of all the pesticides tested, Captan was the only pesticide that was detected in the condensate and resulting retentate and permeate. Captan was not found to be present in the puree. Similar results were found in another study conducted by S. LaVigne, at Gerber Products Company, in which Captan, Orbit, and Methyl Parathion were present in peach condensate, but not in peach puree (LaVigne, 1994).

Conclusion

Pesticides were found in the condensate, permeate, and retentate of the peach samples. The peach process separated the pesticides out of the puree, but left some pesticide residues in the condensate. The amount of pesticides in the retentate and permeate are magnified to some degree. Further investigation is needed to quantify the levels of pesticides present and fully understand the implications that may exist.

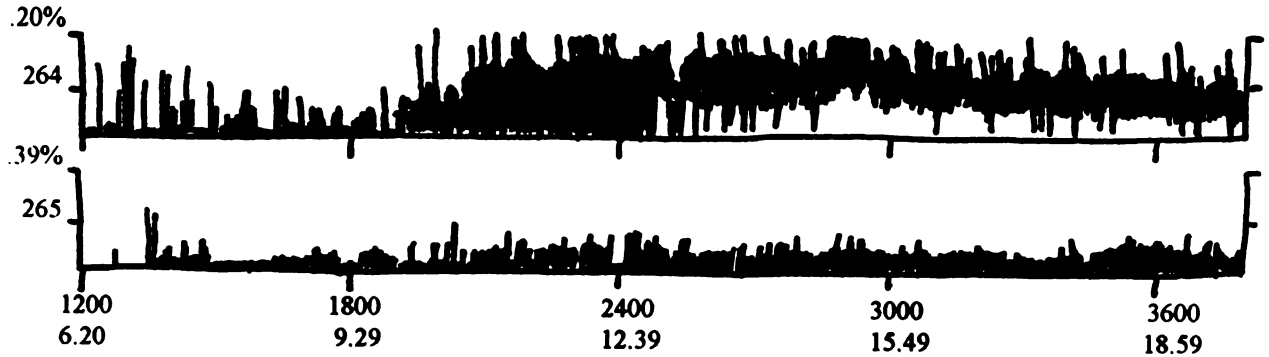


Figure C-1 Gas chromatogram of low acid (LA; A-142) puree M-Para Captan (264) and M-Para II Captan (265)

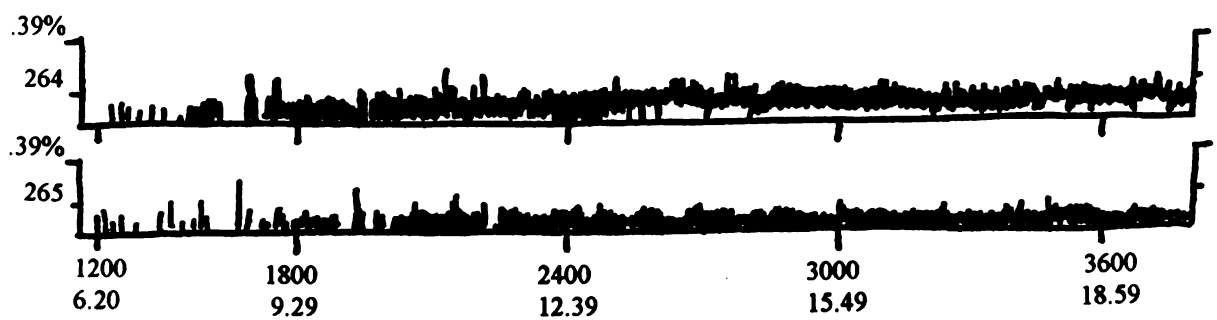


Figure C-2 Gas chromatogram of low acid (LA; A-142) condensate M-Para Captan (264) and M-Para II Captan (265)

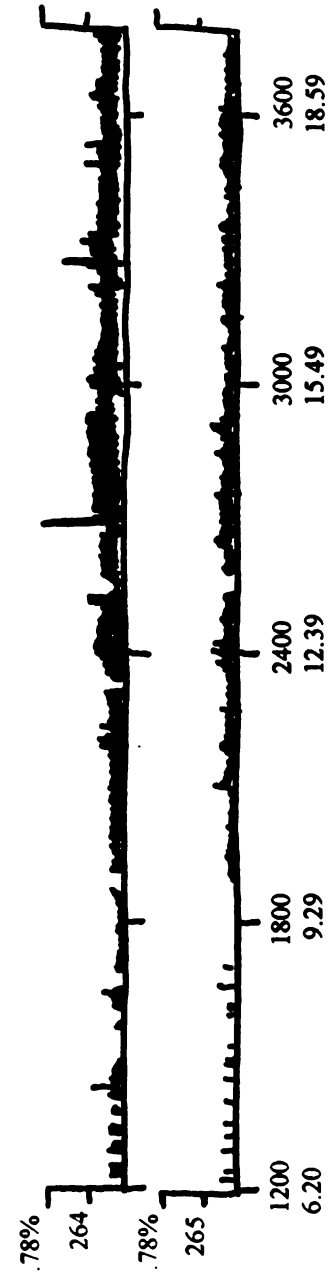


Figure C-3 Gas chromatogram of low acid (LA; A-142) retentate # 4 M-Para Captan (264) and M-Para II Captan (265)

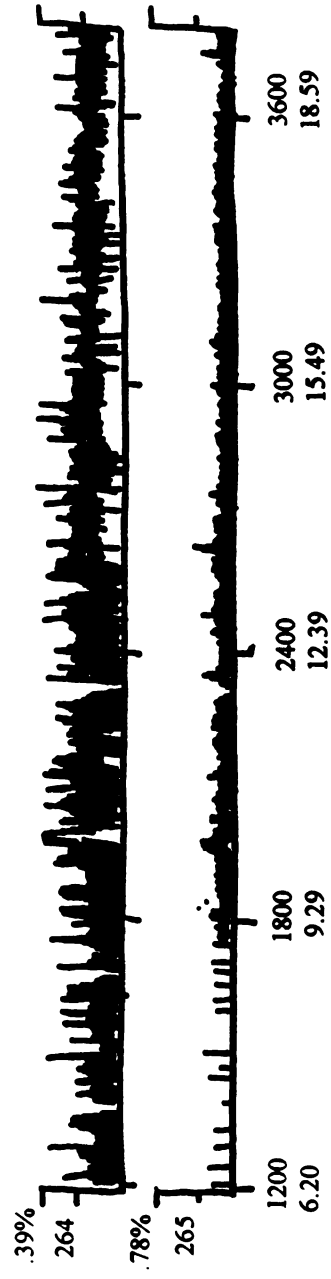


Figure C-4 Gas chromatogram of low acid (LA; A-142) permeate # 4 M-Para Captan (264) and M-Para II Captan (265)

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