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UTILIZATION OF CHEESE WHEY PERMEATE
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Michael J. Saylock

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UTILIZATION OF CHEESE WHEY PERMEATE IN CANNED BEANS AND PLUMS

By

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ABSTRACT

UTILIZATION OF CHEESE WHEY PERMEATE IN CANNED BEANS AND PLUMS

By

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Navy and kidney beans were hydrated in water, then canned in appropriate brines: control, permeate, and lactose-hydrolyzed permeate. Analyses of color, texture, total solids, ash and sensory evaluation were subsequently performed. Hunter Color Difference and Kramer Shear results indicated a general darkening in color and an increased firmness in the treated beans. A significant increase in total solids was observed in the treated samples. Sensory tests indicated that treated beans had significantly lower preference than control and commercial samples.

Plums were canned in a control sugar syrup and in 5, 10, 15, 20, 25% replacements of sucrose with lactose-hydrolyzed permeate (HP), or crystalline glucose-galactose (GG). HP plums were generally darker, but resembled in texture the control samples. Sensory tests showed the plums canned in permeate were similar in acceptance as compared to the control samples.

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INTRODUCTION

Whey, the greenish-yellow liquid produced from the manufacture of cheese has been a thorn in the side of the dairy industry for quite some time. With stiffer governmental restrictions on waste disposal, researchers have been saddled with the problem of changing whey from an economic and environmental liability into a profitable end product.

Whey contains approximately half of the solids of whole milk, depending on the variety of cheese being made. The amount of annual whey surplus has been estimated (Lough, 1974) at 36 billion pounds (2.4 billion pounds of solids), which translates to 1.7 billion pounds of lactose (Hargrove et al., 1976). With the availability of whey expected to keep increasing, new technologies will be needed to utilize whey solids for human consumption. These solids can be a valuable addition to the functional properties of various foods, as well as a source of valuable nutrients. Historically though, whey has been used for animal feed, or dumped down the drain to contribute to the problems of waste disposal. Such disposal of whey causes pollution problems due to its high biological oxygen demand (B.O.D.), and an imbalance between nitrogen and carbon. Typically, one liter of whey

has a B.O.D. of 50,000 mg., compared to one liter of effluent from human population having a B.O.D. of 300 mg (Zall, 1979). This high B.O.D. level causes a severe reduction in valuable oxygen that is needed to sustain aquatic life, clean the water, and destroy dangerous bacteria.

Up until recently cheese plants were large in number but fairly small in size. This made the collection of whey and subsequent condensing, drying, or fractionating processes a rather uneconomical venture. The large volume coupled with the low value of whey made it impractical to transport it long distances for further processing.

Today with fewer but larger cheese plants, the cost for necessary processing equipment may be economically justified.

Ultrafiltration methods are being used more and more for the utilization of whey in the food industry. Whey during ultrafiltration becomes fractionated, yielding a protein concentrate (retentate), and a lactose product (permeate). The permeated fraction accounts for approximately 90% of the whey volume, and contains approximately 85% lactose, 9% minerals, and 4% non-protein nitrogenous materials on a dry weight basis (Khorshid, 1974; Fenton-May et al., 1971).

Most dairy product research in whey protein concentrates has been related to studying them as additives in formulated foods. The work referred to in the literature is concerned with hydrolyzing the permeated fraction to produce

alcohol, oil, single cell protein, and food grade syrups.

This research project is a feasibility study to determine whether the permeate can be used in the formulation of a brine or syrup in the canning industry. The whey permeate lactose, with and without hydrolysis, was investigated for its osmotic properties to evaluate its potential as a brine replacement in canned beans, and as a syrup replacement in canned plums.

LITERATURE REVIEW

In a world of food shortages, the dairy industry is faced with a burdensome surplus of whey solids. Far too much whey has been thrown away without regard to the environmental impact, or the economic potential for whey. However, anti-pollution legislation has stopped such practices as dumping in streams or along sides of a country road, and the whey industry is accepting the fact that they have a consumable product.

Table 1 shows the typical composition of Cottage and Cheddar cheese whey (McDonough, 1976). The data simply shows that most of the solids of whey is lactose. High-quality protein is the second main ingredient, along with small quantities of ash, fat, and lactic acid. Whey is rich in calcium, phosphorous, sodium, essential amino acids, and many vitamins (Cerbulis et al., 1972; Gillies, 1974). The benefits of these ingredients are nutritional however, and can best be realized by addition of whole whey or its fractions into foods. Thus, the recovery of intact whey solids, or a fractionation of them that will alter the ratio of ingredients in favor of lactose or protein, can be quite profitable.

Table 1. Dry solids in cheese whey

% Component	Cottage Cheese Whey	Cheddar Cheese Whey
Protein	13.0	12.9
Lactose	66.5	73.5
Ash	10.2	8.0
Fat	0.1	0.9
Lactic Acid	8.6	2.3

McDonough, (1976).

Methods of concentrating or fractionating whey

The current practical systems for recovering all or part of the solids of whey are discussed below. The techniques of concentration, drying, and reverse osmosis recover all of the solids, while the other systems are fractionating techniques.

1. Concentration reduces the amount of water, thereby lowering shipping costs through reduced bulk, improved keeping quality, and providing a product more suitable for direct use in foods. The cost of removing a pound of water in an efficient evaporator is about one-tenth the cost of removing it in a spray dryer (Morris, 1947). This cost consideration has encouraged the development of more uses of whey and whey fractions in the concentrated form. One major development in this area has been to concentrate whey or whey fractions to 65-70% solids. This causes sufficient lactose crystallization to tie up the rest of the moisture, causing solidification into preformed blocks for use as animal "lick blocks" (McDonough, 1976). Juengst (1979) has reported that fermented ammoniated condensed whey can be an excellent source of non-protein nitrogen, crude protein, and an energy source for ruminants.

2. Drying gives maximum concentration, extends storage stability, and provides a product amenable to food incorporation. There was no satisfactory method for drying whey until D.D. Peeples invented the hydrate drier in 1937. With

this drier, food processors could convert sweet whey into a stable, nonhygroscopic, noncaking product. In this process, high solids whey concentrate is spray dried to a free moisture content of 12-14%, causing lactose to take on a molecule of water and become crystallized. This causes whey solids to convert from a sticky, syrupy like material into a damp powder with good flow characteristics.

Only recently, however, has the problem of drying acid Cottage cheese whey been overcome. The development by R.E. Meade of a dryer that combines spray drying, with through-flow continuous bed drying was instrumental in learning how to dry acid whey (Meade, 1973). The concentrate is spray dried in the hot air chamber to 12-15% moisture. The particles fall to a continuous, porous, stainless-steel belt where lactose undergoes rapid crystallization. Crystallization of lactose before final drying is mandatory for drying acid whey (Young, 1970). The belt conveys the product to another chamber where the whey is further dried by dehumidified air that moves through the porous bed.

3. Lactose crystallization. In the production of lactose, there are two major processes in use today. In the first, the whey protein is chemically solubilized, allowing for higher concentration than normal. The concentrate is then cooled to allow the lactose to crystallize, which is then separated by centrifugation and air dried before

packaging. This process provides a high yield with a single crystallization step (Thurlby and Sitnai, 1976).

In a second, more widely used process, whey is concentrated to somewhat lower levels without chemical solubilization of the protein. After cooling, the lactose crystals are removed by centrifugation and air dried as crude lactose. The crude lactose is refined by deoderizing and washing and filtering. Products that are quite pure are achieved by this method, but the yield is somewhat lower than the first process (Thurlby and Sitnai, 1976).

4. Demineralization is one of the biggest developments in whey processing. The minerals in whey make it distasteful, and they can have an adverse affect on the physical properties of some foods. The two most widely used demineralization processes for whey are ion exchange and electrodialysis.

The ion-exchange process has been known for many years, but its application to whey is fairly recent. The principle is that the whey is passed through two containers which are filled with special synthetic resins which have the ability to exchange ions. In the first container, the special synthetic resins change its hydrogen ions for cations in the whey. Here the positive ions of the salt are captured and acid is formed by the release of hydrogen ions. The whey is then passed over the anion exchanger where hydroxyl ions are exchanged for negative ions of the

salt. When the mobile ions of the resins are completely replaced by other ions, the process discontinues and the resin must be regenerated. This is done by passing an acid (hydrochloric) solution through the cationic exchanger, and a basic solution (NaOH) through the anionic exchanger. There are several technical difficulties in ion exchange, including proper sanitation of the resin beds, disposal of regenerating solutions, the necessity of working at low solids concentration to prevent clogging of the resin beds, and a non-continuous process causing higher labor costs (Short and Doughty, 1977).

Electrodialysis, a combination of electrolysis and dialysis, is the separation of electrolytes, under the influence of an electric potential through semi-permeable membranes. The driving force is an electric field between the anode (positively charged), and the cathode (negatively charged). Between the anode and cathode, a number of ion-selective membranes are placed which are permeable only to anions or cations. Every other membrane has a positive charge repelling positive ions and allowing negative ions to pass, and in between there is a negatively charged membrane doing just the opposite.

The principle is that the whey is pumped through every second space between 2 membranes, and a solution of NaCl (cleaning solution) is pumped through the compartments between the whey streams. The ions move from the whey

stream into the 'cleaning' solution where they are retained, because they cannot move any further. Disposal of the 'cleaning' solution is no problem because it contains only minerals and acid, making the B.O.D. level small. This is an advantage because the membranes can be cleaned chemically (Sammon, 1974).

The Purity Cheese Company has developed a modification of electrodialysis which they call transport depletion (Sheder, 1972). A neutral membrane is used instead of the positively charged membrane. Protein molecules bounce off the neutral membrane and remain in the fluid while the minerals are removed.

5. Protein precipitation. Dairy products are known for their high quality protein; therefore much emphasis has been placed on methods of concentration or recovering the protein fraction from whey. One method is to heat denature the protein in the whey and then recover it by a centrifugation or filtration technique. Variations include the use of a pH adjustment and/or the addition of chemicals such as $AlCl_3$, $FeCl_3$, $CaCl_2$, and $Ca(OH)_2$ (Joly, 1965; Tanford, 1968).

Hydrocolloids like carboxy methyl cellulose (CMC) have also been used to precipitate whey protein (Hill and Zadow, 1974). The CMC combines with the protein, but is not removed. The resulting product is highly viscous, which may or may not be desirable, depending on its use.

Whey protein can also be separated by complexing with iron salts. The complex is called ferric-whey protein, and is useful for iron fortification of some foods (Amantea et al., 1974).

None of these precipitation methods are advantageous because the proteins are denatured causing a lack of solubility and functionality.

One method was developed to recover undenatured whey protein by precipitation with long-chain polyphosphates. When the pH is 5 or below, the protein molecules will complex with the polyphosphate, and can be removed by centrifugation (Weller, 1979).

6. Gel filtration is another fractionating process that is being used commercially. In this process, a cross-linked dextran gel (Sephadex) that exists in the shape of beads is packed in a column. The Sephadex beads contain pores, and as the whey is passed through the bed, the protein molecules remain in the flowing volume because they are too large to penetrate the gel particle. Smaller molecules, such as salts and lactose, penetrate the gel pores to varying extents and are eluted at a slower rate. Thus, molecules are eluted in order of decreasing molecular size, and the whey protein is effectively separated from smaller components (Knipschildt, 1977).

The major process used in this country involves a series of unit operations. Whey is treated to remove

insoluble protein and fat, then one-half the lactose is removed by concentration and crystallization. Finally the product is gel filtered, concentrated, and dried (Lindquist and Williams, 1973). In another process, an ultrafiltration procedure is combined with Sephadex gel filtration to produce a powder containing 90% protein (McDonough, 1976). The powder has excellent solubility and stability at a wide range of pH.

7. Reverse Osmosis (RO)/Ultrafiltration (UF). The related RO/UF membrane processes have become major factors in the field of whey concentration and fractionation. As early as 1970 it was reported that significant advances were being made in the design of RO/UF systems (Webb, 1970). At this time, other studies were describing the commercial performance of an RO system for whey concentration (McDonough, 1971; Peri and Dunkley, 1971), and the development of a two-stage process using RO and UF for the fractionation and concentration of whey (Horton et al., 1970; Fenton-May et al., 1971), as seen in Figure 1.

RO and UF are pressure activated processes that separate components on the basis of molecular size and shape. While these terms are used interchangeably, the following distinction should be made between these processes. RO is that process in which virtually all species except water are rejected by the membrane. The osmotic pressure of the feed stream in such a system will often be quite high.

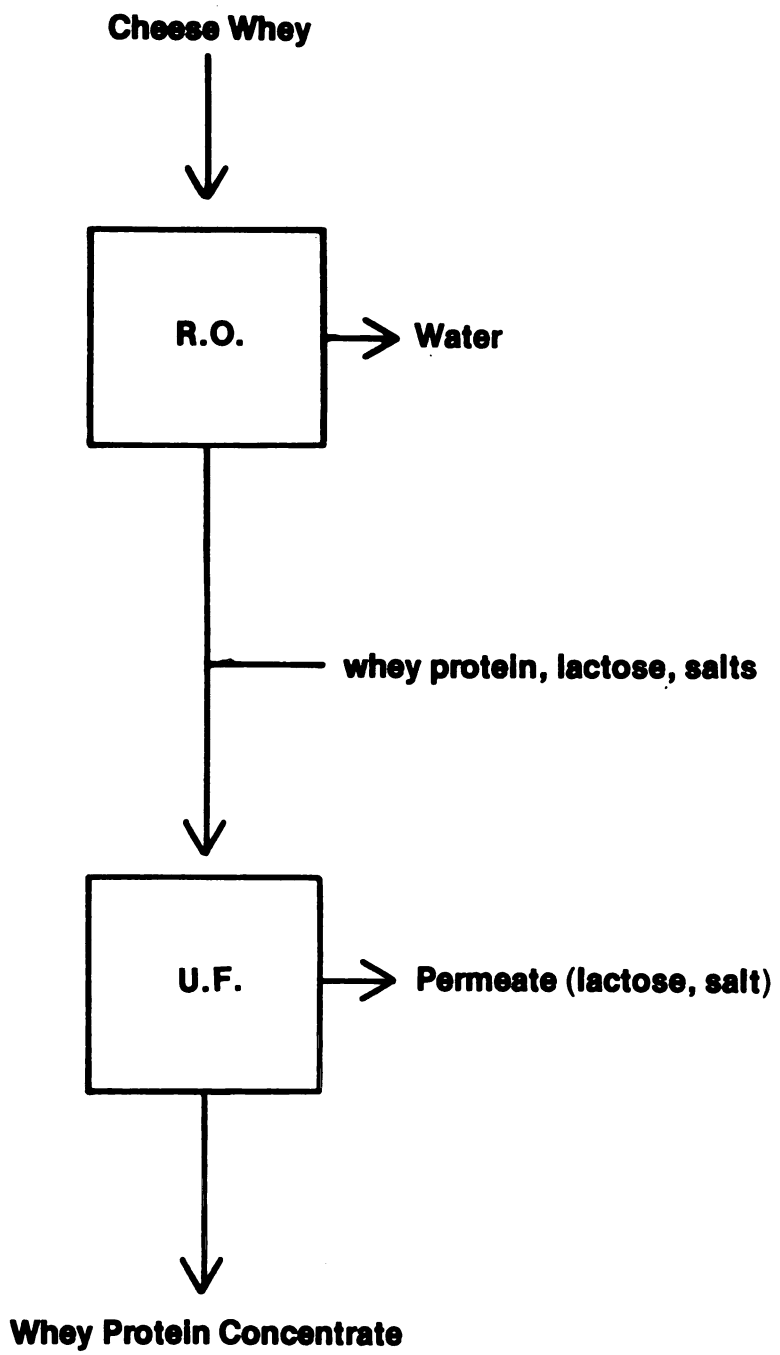

Figure 1: Schematic diagram of related RO/UF processes.

Consequently, in order to achieve adequate water flux rates through the membrane, such systems often utilize hydrostatic operating pressures of 5883.6Kg/cm^2(600 psi) or greater (Eriksson, 1974). On the other hand, the term ultrafiltration refers to the process in which the membrane is permeable to relatively low molecular weight solutes and solvent (permeate), but is impermeable to higher molecular weight materials (retentate). The permeability and selectivity characteristics of these membranes can be controlled during the process so that they will retain only molecules above a certain molecular weight (Michaels, 1976). Thus, UF is a selectively fractionating process.

In order to meet the stringent sanitary requirements of the food industry, most RO/UF equipment used in food processing is based on a configuration in which the membrane is cast on the inside of a porous tube (Michaels, 1976). This tube may vary in diameter from 1/2" to 2" (Resik et al., 1971). It provides the necessary mechanical support to enable the membrane to withstand the stresses imposed by the hydrostatic pressure used in the process.

One advantage of UF over other processes is that by varying the amounts of permeate removed, a wide variety of protein concentrates, ranging up to 60% protein can be obtained (McDonough, 1971). Higher levels can be obtained by simultaneously adding fresh water and concentrating by UF.

Utilization of Whey Solids in Foods

Recognition is finally being given to the food value of whey and whey ingredients in human nutrition. As late as 1960, practically all of the whey produced was either dumped, or went into animal feed. As anti-pollution legislation was approved, research became involved with incorporating whey solids in human food.

For 1976, total production of fluid whey was estimated at 34.2 billion pounds, in which 2.2 billion pounds of whey solids were produced (Table 2). This shows a dramatic increase (21.7%) from 1972 when 28.1 billion pounds of fluid whey, and 1.8 billion pounds of whey solids were produced (Clark, 1979).

Most whey is being used as a replacement for non-fat dry milk (NFDM). The growing use of whey solids corresponds to the fact that in recent years, whey has been elevated in status from a by-product or waste product, to one that should be used on its own merits. Some characteristics of its own favor its use over non-fat dry milk. An example is its ability to accentuate flavor. O'Connell (1974) was able to reduce both the sugar content, and the amount of chocolate liquor needed in candy bars. Whey accentuated the chocolate flavor so well, that less was needed.

Whey also accentuates the flavor of a number of fruit flavored drinks (Nelson et al., 1972). So whereas casein in NFDM masks flavor, whey permits a reduction in flavor

Table 2. Estimated U.S. fluid whey and whey solids production and quantity of whey solids "further processed"

	1973	1973	1974 (millions of pounds)	1975	1976
Sweet-type whey					
Cheese production	2,605	2,685	2,937	2,811	3,337
Calculated fluid whey	23,445	24,165	26,433	25,299	30,033
Calculated whey solids	1,524	1,571	1,718	1,645	1,952
Acid-type whey					
Cottage cheese production	784	763	690	701	711
Calculated fluid whey	4,704	4,578	4,140	4,206	4,266
Calculated whey solids	306	297	269	273	277
Total whey production	28,149	28,743	30,573	29,505	34,299
Total equivalent whey solids	1,830	1,868	1,987	1,918	2,229
Total whey solids further processed (%)					
Total whey solids manufacture X 100/ total equivalent whey solids	53.2%	55.0%	56.5%	60.0%	56.7%

Clark, (1979).

ingredients (Knipschildt, 1977). Webb (1970) was able to describe specific processes for the manufacture of whey drinks from prune and tomato juice.

The baking industry is the largest user of edible whey in the U.S. for bakery products. Whey providing all of the attributes of milk except water absorption and protein content. Therefore, whey is generally combined with other ingredients, such as soy flour, that compensate for those deficiencies. A number of other ingredients (egg white solids, calcium salts, etc.) are added to whey to give a larger variety of blends designed specifically for certain performance characteristics (Daniel, 1978).

Whey is also used in other dairy products, especially ice cream. U.S. federal regulations permit the use of whey in ice cream up to 25% of the serum solids used (Bills, 1974). Leighton (1944) pioneered a set of recommended optimum substitutions of whey solids, depending on the % fat in the mix. Potter and Williams (1949) demonstrated that good quality sherbet could be made by using whey solids in place of other nonfat milk solids. Frazeur and Harrington (1967) showed that consumers could not distinguish between a controlled ice cream, and one where 25% of the serum solids was replaced with demineralized whey. Consumers could distinguish between ice creams where 25% of the serum solids was replaced with either an average or high quality whey, and the control and demineralized

samples. Arnold et al. (1976) showed that the use of up to 35% serum solids replacement with dried sweet whey was acceptable in ice cream mix formulations. Substitutions of up to 50%, using hydrolyzed whey concentrate from UF, have also been shown to be acceptable (Loewenstein et al., 1976).

Another use is in cheese foods and spreads. The use of retentates from UF has been explored for quite some time (Kosikowski and Sood, 1979; Kosikowski and Covacevich, 1978). A method for making process cheese, supplemented with plain and enzyme-treated highly concentrated retentates has recently been developed (Kosikowski and Kumar, 1977). Ernstrom et al. (1978) converted ultrafiltered whole milk retentates into curd as material for process cheeses.

The making of natural cheese utilizing highly concentrated retentates was introduced by Maubois and Mocquot (1975). Cottage cheese produced from UF retentate was shown to be acceptable (Mattews et al., 1976).

Whey and modified whey blends are being used increasingly in cake mixes (Scanlon, 1974), sausage products (Lauck, 1975) and confectioneries (O'Connell, 1974).

Utilization of Whey Components

Whey protein (WP) has nutritional and functional properties that make it unique. In determinations of protein quality, results have shown the nutritional superiority of

WP over casein. The Protein Efficiency Ratio (PER) for WP is 3.1-3.2 when casein is standardized at 2.5 (Wingerd et al., 1970). In practical terms, WP is ideal as a supplement to other foods of lower value. A combination of proteins from different sources has potential for improving the PER by having the amino acid profile of one protein complement the amino acid profile of another protein. Womack and Vaughan (1972) supplemented cereal grains with WP prepared by UF. Supplementation of up to 50% improved the PER drastically.

In addition to nutritional benefits, WP has desirable functional properties. Undenatured protein prepared by UF and gel filtration retains excellent solubility, even in an acid environment. This property makes WP the nutrient of choice in the fortification of soft drinks (Knipschildt, 1977).

WP concentrates are excellent foaming agents; under certain conditions, they produce excellent stable whips. Unfortunately, when the foams are subjected to heat they become very unstable. Thus, the whipping properties of WP have been found to be quite acceptable in dessert toppings, as reported by Gillies (1974).

WP makes an excellent binder for meat products. Frankfurters containing WP were judged to have superior color, texture, and eating properties, to those frankfurters containing non-fat dry milk (Lauck, 1975). The lack of water

binding capacity of WP, accounts for low viscosity even in highly concentrated solutions, giving excellent gelation and emulsifying properties, which are similar to that of sodium caseinate (Lauck, 1975).

Lactose is more than just a carbohydrate. It has physical and chemical properties that give it a distinct advantage over other sugars in certain foods and pharmaceuticals. Lactose is recognized as an aid in absorption of calcium and phosphorus (Ali and Evans, 1973). Welch (1965) found that lactose could be used as a carrier for dispensing potent food flavors. Lee and Lillibridge (1976) were able to use lactose as a carrier of antibiotics. Because of its excellent tablet forming properties, lactose influences the characteristics of the tablet---its strength and ease of dissolving. Chambers and Ferretti (1979) have studied the use of whey/lactose in a binding system to manufacture iron ore and iron/steel pellets produced from iron fines captured in pollution control equipment. Lactose also contributes a number of improved qualities to baked goods (Ash, 1976; Guy, 1971). In such products, lactose can contribute to flavor, texture, appearance, shelf life, and toasting qualities. Improved tenderness in biscuits (Potter and Zaehringer, 1965) and doughnuts (Hoffstrand et al., 1965) has been attributed to lactose. Guy (1971) found that lactose not only improves the color and texture of the crust of many baked goods, it also

improves toasting qualities through participation in the Maillard reaction. Jelen and Breene (1973) used lactose to improve the texture in dill pickles. Since other sugars were fermented out, lactose improved the brittleness, hardness, and elasticity of the dill pickles.

Since lactose is less sweet than sucrose, it can be added to foods such as icings, toppings, and fruit pie fillings to increase the total solids without excessive sweetness (Jonas, 1973). At low concentrations, lactose is only about one-fourth as sweet as sucrose, but at higher levels it is about half as sweet (Pangborn, 1963). Thus, far more lactose can be used in foods without making them excessively sweet. Replacing 15-20% of the sucrose in icings and toppings with lactose, not only reduces the sweetness, but can improve texture and stability (Reger, 1958). Other workers (Randeria, 1966; Welch, 1965) have suggested similar replacements of sucrose by lactose in foods such as custard, fruit pies, and jams. Increasing the sugar solids without causing excessive sweetness can aid in improving texture, viscosity, and mouth feel.

In cultured products lactose gives more body and smoothness and reduces the sharp acid flavor (Reger, 1958). Various proteins have been stabilized by the use of lactose. The casein system of milk remains stable due to the presence of lactose. Once the lactose is removed the casein is destabilized (Gerlsma, 1957). Studies with chocolate and

chocolate drinks have shown that lactose containing samples were preferred for homogeneity, texture, and aroma (Arnott and Bullock, 1963).

Lactose does have its limitations in foods. It is not very soluble at room temperature, so crystallization can occur if too much is used, causing sandiness (Nickerson, 1956). The other limitation is the lactose-intolerance problem, found in individuals or species of animals that lack the enzyme necessary to handle large amounts of ingested lactose.

These limitations are overcome by hydrolysis of lactose by acid or enzymes into its component monosaccharides, glucose and galactose, thereby increasing usefulness of lactose. Hydrolysis expands lactose possibilities in foods by markedly affecting relative sweetness, solubility, and crystallization (Bouvy, 1975; Holsinger and Guy, 1974).

Hydrolysis of lactose can be by acid or by enzyme. The use of β-galactosidase, either in a batch process or as an immobilized enzyme has been studied carefully. Pitcher (1975) and Weetall (1976) studied operational parameters important to the function and scale-up of immobilized enzyme systems. Bouvy (1975) developed specific parameters (amount, time, temperature, pH, etc.) for the enzyme's use.

Acid hydrolysis has been accomplished with strong mineral acids or with ion-exchange resins in the acid form. High temperatures are required in both cases (Coughlin and

Nickerson, 1975; Haggett, 1976). Guy and Edmondson (1978) developed a method for producing nearly colorless syrups by either acidic or enzymatic hydrolysis, followed by decolorization, ion exchange demineralization, and concentration. Kosikowski and Weirzbicki (1973) reported that glucose-galactose syrups prepared by acid hydrolysis have been suitable for blending to prepare swiss-style flavored yogurts, imitation maple syrups, fruit juices, and puddings. Holsinger (1978) reported that lactose-treated whey reduced sandiness and permitted a 10% sucrose reduction in ice cream. Crystallization was reduced and browning enhanced in caramel manufacture.

Hydrolyzed whey permeate obtained from UF, has recently been studied for human food use. Fenton-May et al. (1971) and Khorshid (1974) studied UF permeate to determine its nutritional composition. Palatable wines containing 10-12.5% alcohol were produced when yeasts were fermented with hydrolyzed whey permeate syrups and grape juice concentrates (Roland and Alm, 1975). Fermentation times can be reduced drastically when lactose hydrolyzed whey is used for wine production (O'Leary et al., 1977). Kosikowski and Gawel (1978) adapted lactose-fermenting yeasts to ferment concentrated ultrafiltered Cottage cheese whey permeates to a high yield of alcohol, approximately 10% (v/v) ethanol in 15 days at 30^{o}C. Cheese whey and UF permeate have been used as media for producing oil and single-cell protein

from strains of yeast. Fermentation of UF whey permeate has been much more successful, producing oil, reducing the chemical oxygen demand (COD) by 95%, and requiring the fewest additions of nutrients (Moon et al., 1978). MacBean (1976) has successfully hydrolyzed permeate with ion-exchange resins, and has studied the mechanism and characteristics of the resin, and operational variables such as temperature and flow rate. These hydrolyzed syrups have been used to partially substitute for sucrose in canned peaches and pears (Tweedie and MacBean, 1978). Their results show that up to 50% of sucrose in the syrup of these canned fruits can be replaced with hydrolyzed lactose without reducing quality.

EXPERIMENTAL PROCEDURES

Materials

Obtaining the permeate

For this study, uncolored Cheddar cheese whey was obtained from the Michigan State University Dairy Plant. This type of cheese whey was selected because:

1) Cheddar cheese whey is the predominant form produced in the U.S.A., and
2) It was obtained as a byproduct from the cheese batch in which no color was added. Lack of added color was deemed advisable to prevent possible side effects in the final canned product.

The uncolored Cheddar cheese whey was then ultrafiltered using an ABCOR 2-Tube through 10-Tube Sanitary Test Ultrafiltration System (Figure 2). Ultrafiltration (UF) is the process of separating whole whey into its component parts, depending on their molecular weights. This is done by applying pressure to push the smaller molecular weight materials (lactose, minerals, salts, etc.) through a semi-permeable membrane physically arranged to maximize its surface area. The fraction filtered through the membrane (water, soluble sugars, minerals) is termed the permeate, and the fraction that is impermeable to the membrane (fats,

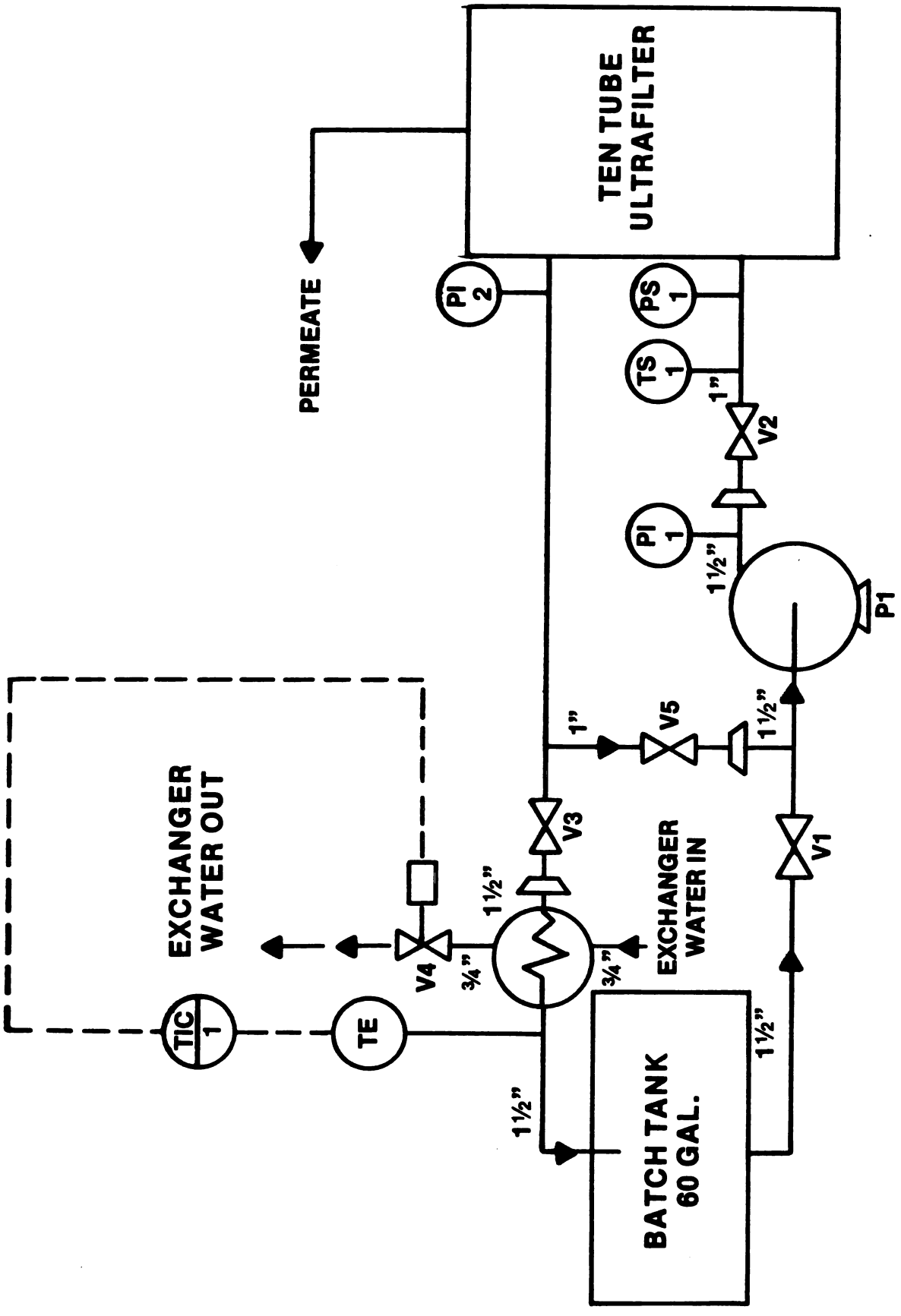

Figure 2: Schematic diagram of Abcor Ultrafiltration System.

proteins) is termed the retentate.

The UF system used in this study employed tubular membranes, SHFM-180-S-G, each having an active membrane surface of 0.10 m^2. Instead of 10 tubular membranes, an 8-tube system (0.82 m^2 surface area) was used because 2 tubes were improperly sealed, causing leaks to occur. Approximately 151.4165 l (40 gallons) of whey at an optimum operating temperature of 47 to 49°C were placed in the feed tank. The system's centrifugal pump was turned on, and simultaneously the inlet and outlet valves were adjusted to 196.12 kg/cm^2 (20 psi) and 441.27 kg/cm^2 (45 psi) respectively. Both the initial and final flux rates (permeate rate of flow) were exactly the same (29.7 ml/sec.) for the entire processing run. It took approximately 1 hr to filter 75 percent of the whey.

The permeate was collected in 37.8 l (10 gallon) milk cans and then frozen at -30°C to prevent microbial spoilage. The centrifugal pump was shut down forcing the remaining retentate to recycle back to the feed tank. This was allowed to drain and then the entire system was flushed with water at ambient temperature until it appeared clear. The feed tank was then filled with 113.5 l (30 gallons) of ambient water and 355 g of "Dishmate" (Calgon Inc., St. Louis, MO). The cleaning fluid was recirculated for 10 min and then drained. Thirty gallons of cold water (3-5°C) and 227 g of concentrated phosphoric acid (85 percent) were

added to the feed tank to reduce the pH to 2.5, and the acid cleaner was recirculated for another 15 min. The combined effect of these treatments was to cleanse, and neutralize the pH of the membranes. Finally, a treatment of 20 to 25 ppm chlorine was used to rinse the entire UF system.

Hydrolysis of the permeate

To enhance the sweetening effect of the permeate, lactase enzyme "Maxilact," produced by the Enzyme Development Corporation (N.Y.C.) was used to split lactose into glucose and galactose. Though an optimal pH of 6.5 to 7.0 is required for this enzyme, the pH of the permeate was between 5.8 and 5.9. Therefore, subsequent addition of 0.1N NaOH was needed to raise the pH to 6.5-7.0. After this was done, 0.3 g of "Maxilact" (freeze-dried powder) was added to one liter samples, mixed, and then incubated at 35^{o}C for 3 hr to assure 90 percent hydrolysis of lactose (Bouvy, 1975). The samples were heated to 63^{o}C for 30 min to inactivate the enzyme, then stored under refrigeration until canning took place (2 to 3 days).

Bean preparation

Both dry navy and kidney beans were handled and prepared for canning in the same manner. Beans were adjusted to uniform moisture content. Each individual sample to be canned was initially weighed at exactly 135 g fresh wt. (129.6 g solids). The procedure of hydration was done in two sequential steps. First the bean samples were placed in wire baskets with water at ambient temperature (21^{o}C) for

30 min. This was done in order to slowly soften the hard exterior coat, thus preventing seed coat rupture. Immediately after this the beans were placed in 88 to 90°C water for 30 min. Rapid hydration occurred, raising the bean moisture content from an initial 4 percent to approximately 48 percent.

Following hydration, the beans were placed in #303 cans and filled with an appropriate brine. The brines consisted of:

1) A control, which was a standard mixture of 9.46 l of water, 113.6 g of salt, and 114.2 g of sugar,
2) Ultrafiltered whey permeate plus 113.6 g of salt, and
3) Hydrolyzed whey permeate plus 113.6 g of salt.

Brines #2 and 3 contained salt in order to enhance flavor. They did not contain extra sugar because of the lactose or hydrolyzed lactose (glucose and galactose) inherently present.

Finally, the cans were exhausted, sealed and processed at 115°C for 45 min. Analytical procedures were performed at least one week after processing to insure adequate equilibration in the cans.

Plums and syrup preparation

Canned plums were prepared from previously frozen Stanley plum halves. Syrups were prepared such that each can (plums and syrup) was equilibrated to 20° Brix. The frozen plums were thawed under refrigeration, then random samples were mixed in a blender to form a slurry. Samples of this

slurry were analyzed using an Abbe refractometer to determine degrees Brix. It was determined that the plums had a Brix of 13^{o}.

Each #303 can contained 284 g of plums, and 170.4 g of syrup. The required initial concentration of sucrose syrup to yield the equilibrated end point of 20^{o}B was calculated as follows:

16 oz (454 g)/can X .20B = 90.88 g

10 oz (284 g) plums X .13B = 36.92 g

6 oz (170.4 g) syrup X = 53.88 g

Therefore each syrup had to contain 53.88 g of sucrose per can.

Syrups consisting of 5, 10, 15, 20 and 25 percent replacement of sucrose with hydrolyzed permeate were prepared. The syrups that contained 10 percent or less hydrolyzed permeate, were made using the hydrolyzed permeate in its natural form (approximately 95 percent water, 4.5 percent lactose, and 0.5 percent minerals). For syrups that had a higher replacement percentage, the hydrolyzed permeate was concentrated by freeze drying using the following procedure:

1) Pouring it into one inch deep aluminum pans.
2) Freezing it at -30^{o}C.
3) Placing it in a freeze-dryer (Repp Industries Sublimator Model #40).

4) Turning the condenser refrigeration unit on.
5) When the temperature reached -35°C, the vacuum pump was turned on.
6) When the temperature reached -40°C, the shelf heat was turned on. The glycol setting was at 25°C to assure rapid enough moisture loss without any adverse qualitative effects.
7) After 24 hr, the refrigeration, heating, and vacuum units were shut down. After the vacuum was released, the freeze-dried hydrolyzed permeate was removed.
8) Finally, it was scraped from the aluminum pans, put into glass beakers and stored in a desiccator until the syrups were made.

Analytical Procedures

Ultrafiltered whey permeate was analyzed for pH, total protein, total solids and ash by the procedures given below. After canning, the samples were taken directly from the can and analyzed for color differences by the Hunter Color and Difference Meter. Following this, the solid beans and plums were analyzed for drained weight and subjected to shear force measurements with the Kramer Shear Press. Both the juice and solids from the canned beans and plums were analyzed individually for total solids, ash, and mineral content.

1. Drained weight

Canned navy and kidney beans were emptied onto a number 8 mesh screen (0.235 cm openings) and washed by a slow swirling motion for 1 minute in 21^{o}C tap water to remove adhering brine. The screen was drained at a 15^{o} angle for 2 min. Bean weight was recorded as washed drained weight.

The same method was used for the canned plums except the washing step was omitted.

2. pH

The pH measurements were made using a CHEMTRIX Type 60A digital pH/mv meter. Before testing, the pH meter was standardized with a standard buffer solution of pH 4.01, and manually set for the temperature of the product. The pH of all samples were determined to the nearest 0.1 pH unit.

3. Total protein

The total protein of the ultrafiltered whey permeate was determined by the Kjeldahl method for determination of total nitrogen (A.O.A.C. 1975). A 3.5 g sample was weighed into a digestion flask. About 0.7 g of HgO and 20 to 30 ml of concentrated H_2SO_4 was added to the sample. The flask was then placed in an inclined position and heated to just below the boiling point of the acid, or until the frothing had stopped. The heat was then increased so that the acid boiled rapidly and the mixture became colorless. The sample was allowed to digest until oxidation was complete

(about 2 hr).

After cooling, the solution was diluted with 200 ml of distilled water. A few pieces of pumice stone were added to prevent bumping, along with 25 ml of Na_2S. Fifty milliliters of NaOH solution (11.25 N) were added to make the solution strongly alkaline. This was done by pouring the NaOH slowly down the side of the flask. The solution was connected to a condenser, thoroughly mixed, then distilled until all of the NH_3 had passed over into a measured quantity of standard acid (0.1 N HCl). This was titrated with a standard alkali solution (0.1 N NaOH), using methyl red as the end point indicator.

4. Total solids

Total solids of the whole whey, and of the permeate were determined according to the Mojonnier Method for total solids (Mojonnier, 1925). A sample (2 g) was weighed into a flat bottomed (7.6 cm diameter by 2.5 cm high) aluminum dish. The sample was spread over the entire bottom of the dish, and then placed on a hot plate until the first trace of brown appeared. As soon as this happened, the dish was placed in a vacuum oven at 100°C for 10 min, under a vacuum of not less than 20 inches of mercury. The dish was then placed in a desiccator and slowly brought to room temperature, then weighed in order to calculate solids.

Total solids of both the canned bean and plum solid and juice were determined by official methods of analysis

(A.O.A.C. 1975). Solid beans and plums were placed in a blender and mixed into a slurry consistency. Five grams of solid or 10 g of appropriate juice (brine or syrup) were weighed into a flat bottomed dish. The dish was then placed into a drying oven for 18 hr at 100°C, after which it was removed, placed in a desiccator, cooled and then weighed. The amount of residue remaining was reported as percent total solids.

5. Ash

Ash in the bean, plum, and permeate samples was determined by A.O.A.C. (1975) procedures. Ten milliliters of either permeate, bean, or plum juice (5 g of solid bean or plum) were placed in a porcelain crucible which had already been adjusted to a constant weight. The crucible was then placed in a drying oven (100°C) for 18 hr. After this, the crucible was removed and cooled in a desiccator to room temperature. The sample was then pre-ashed by holding over a Bunsen burner to ignite the dry matter. When flaming ceased, incineration was completed in a muffle furnace at 530°C for 18 to 20 hr. The remaining gray-white residue was removed from the furnace and placed into a desiccator, cooled and weighed to determine the percent ash.

6. Color difference

The Hunter Color Difference Meter (Model D25-2) was used to detect color differences in each sample. The

initial procedure was to turn the color meter on, allow it to warm up for about 30 min. The color parameters of the colorimeter were standardized with a known standard (L=95.35 +a=-0.6+b=+0.4). Basically this colorimeter consists of a light source, a sample viewing port, a set of filters which duplicate the responses of the receptors in the human eye, a photocell and the sample. Light is directed toward the sample, and the reflected light measured by the photocell.

Individual samples of 100 g were weighed and placed into a glass dish. The sample was then placed over the light source, and digital read-outs for each of the 3 color parameters (L, a_L, b_L) were recorded. The L scale in the vertical axis ranges from 0 (black) to 100 (white). The two horizontal scales represent $+a_L$ (redness) to $-a_L$ (greenness), and $+b_L$ (yellowness) to $-b_L$ (blueness) as shown in Figure 3.

7. Shear force

The Kramer Shear Press, Model SP-12lMP with recording attachment, was used with a 1360 Kg. ring and a Model CS-1 standard shear compression cell. Textural characteristics were determined by measuring the degree of deformation of the proving ring, resulting from the force required to compress and shear the bean or plum sample in the test cell. The procedure was as follows:

1) A one hundred gram sample of solid plums or beans was weighed and placed into the bottom of the test cell.

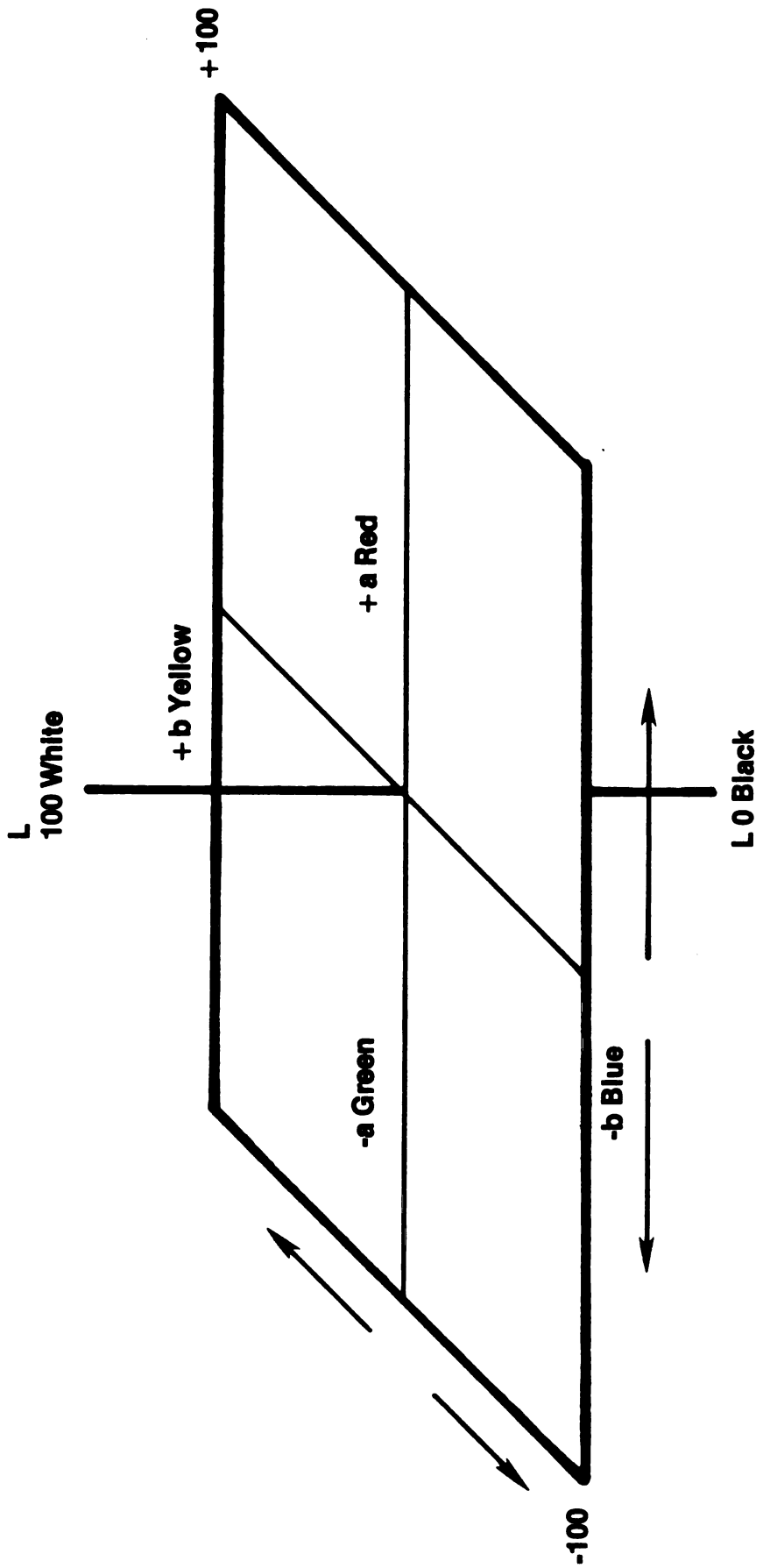

Figure 3: Hunter L.a.b. Opponent Color Solid

2) The element was attached to the transducer ring and the cell box with the weighed sample covered, was placed in the proper position.
3) Range was set at 10, thus full scale represented 136 kg = XKg force.
4) Recorder pen was set at zero.
5) The shear blades were passed through the sample and the resistance was recorded on chart paper.
6) Readings on each sample were obtained in duplicate. Calculations for lb. force shear resistance per gram sample were made using the following formula:

$$\frac{\text{lb. ring} \times \frac{\text{range}}{100} \times \frac{\text{peak height}}{100}}{\text{weight of sample}} = \text{lb. force/g}$$

Navy bean results were obtained from two peaks of bean deformation. The first peak shows the amount of force required for the proving ring to compress the bean's outer layer before it ruptures. The second peak is the force needed for the proving ring to compress and shear the internal portion of the bean.

8. Minerals

The mineral content of navy beans, kidney beans, plums and their respective brines or syrups were analyzed using a direct reading spectrograph, or photoelectric spectrometer "Quantograph" manufactured by Applied Research

Laboratories, Inc. maintained in the Horticulture Dept. of Michigan State University. The basic operational principle of this unit is that of an emission spectrograph as described by Kenworthy (1960). Samples were analyzed for P, Na, Ca, and Mg.

Sample preparation for mineral analyses involved the ashing of 0.5 g samples (dry matter) overnight at 530°C. The ash was then dissolved in the ashing crucible with 5 ml of HCl-Co-Li-K solution. The HCl-Co-Li-K solution was prepared by dissolving 142.6 ml HNO_3, 34.07 g KCl, 38.22 g LiCl, and 2.02 g $CoCl_2$ in one liter of distilled water. A portion of the ash solution was transferred to a porcelain boat with a medicine dropper. This ash solution was used directly in the excitation process by use of a revolving disc electrode. The amount transferred is not critical, but should be sufficient to provide a good contact between the revolving disc electrode and the solution. Also, it is necessary to provide enough solution to prevent complete evaporation during the excitations.

Excitation was accomplished by the use of an interrupted arc discharge that produces a uni-directional spark-like condition. Values were read in a recording chart to the nearest half division. A computer program was used to express ppm or percentage on a dry basis. The results in this study are expressed as mg/100 g of fresh weight.

9. Sensory evaluation

Sensory analyses were made by a consumer panel to determine both difference and preference among treatments. The untrained panel consisted of a random sampling of people working and/or passing through the MSU Food Science Building. All samples were served in segregated panel booths, where each panelist was provided with comfortable seating, proper lighting, water for oral rinsing, and enough space for samples and for the score card.

A triangle difference test was used to evaluate treatment differences for navy beans. A sample form is shown in Figure 4. Three sets of 3 samples each were presented individually to the panelist at one sitting. Panelists were instructed that two of the three samples were identical and one was different. They were instructed to identify the odd sample. In addition, they were instructed to indicate the sample possessing the greater degree of sweetness, tenderness, as well as better color.

Preference testing was done to determine directly which sample(s) the panelist liked or disliked. Included in the experimental samples of beans was a commercial brand. A simple seven point hedonic scale was used for all attributes ranging from 7 equals very dark color, very strong flavor, very firm/dense texture, very acceptable, and like extremely. A sample form is shown in Figures 5 (for beans) and 6 (for plums).

TRIANGLE TEST

PRODUCT: CANNED NAVY BEANS

In each set, two of the samples are identical, one is the odd or different sample. Test to determine the odd sample. If you are not sure, take a guess. Answer the specific attribute questions about the sample in each set.

SET NUMBER 1

Samples Presented: ____ ____ ____
Different/Odd Sample Is: ____

Which is sweeter?. . . . . odd sample( ). .paired sample ( )
Which one do you prefer? . . . . . odd sample( ). .paired sample ( )
Which are more tender? . . . . . odd sample( ). .paired sample ( )
Which one do you prefer? . . . . . odd sample( ). .paired sample ( )
Which color do you prefer? . . . . . odd sample( ). .paired sample ( )
Comments, if any: _____

SET NUMBER 2

Samples Presented: ____ ____ ____
Different/Odd Sample Is:____

Which is sweeter?. . . . . odd sample( ). .paired sample ( )
Which one do you prefer? . . . . . odd sample( ). .paired sample ( )
Which are more tender? . . . . . odd sample( ). .paired sample ( )
Which one do you prefer? . . . . . odd sample( ). .paired sample ( )
Which color do you prefer? . . . . . odd sample( ). .paired sample ( )
Comments, if any_____

SET NUMBER 3

Samples Presented: ____ ____ ____
Different/Odd Sample Is:____

Which is sweeter?. . . . . odd sample( ). .paired sample( )
Which one do you prefer? . . . . . odd sample( ). .paired sample( )
Which are more tender? . . . . . odd sample( ). .paired sample( )
Which one do you prefer? . . . . . odd sample( ). .paired sample( )
Comments, if any_____

Figure 4. Sample form of questionnaire presented to untrained panel to evaluate sweetness, tenderness, and color

TASTE TEST

PRODUCT: CANNED BEANS

Instructions: You will be given four servings of a food to eat, and you are asked to say about each how much you like it or dislike it.

SHOW YOUR REACTION BY CHECKING ON THE SCALE

CODE: ____	CODE: ____	CODE: ____	CODE: ____
____Like extremely	____Like extremely	____Like extremely	____Like extremely
____Like moderately	____Like moderately	____Like moderately	____Like moderately
____Like slightly	____Like slightly	____Like slightly	____Like slightly
____Neither like nor dislike	____Neither like nor dislike	____Neither like nor dislike	____Neither like nor dislike
____Dislike slightly	____Dislike slightly	____Dislike slightly	____Dislike slightly
____Dislike moderately	____Dislike moderately	____Dislike moderately	____Dislike moderately
____Dislike extremely	____Dislike extremely	____Dislike extremely	____Dislike extremely

Figure 5. Sample form of questionnaire presented to untrained panel to evaluate preference between separate groups of canned navy beans and kidney beans.

Instructions: Evaluate color, flavor, texture, general acceptability and overall preference of each sample according to the appropriate 7 point rating scale for each attribute. Record results in table below each attribute.

	Color	Flavor	Texture	General Acceptability	Overall Preference
	7 very dark	7 very strong	7 very firm/dense	7 very acceptable	7 like extremely
	6 mod. dark	6 mod. strong	6 mod. firm/dense	6 mod. acceptable	6 like moderately
	5 slt. dark	5 slt. strong	5 slt. firm/dense	5 slt. acceptable	5 like slightly
	4 neither dark/ light	4 neither strong/ mild	4 neither firm/ soft	4 neither acceptable/ unacceptable	4 neither like nor dislike
	3 slt. light	3 slt. mild	3 slt. soft/mushy	3 slt. unacceptable	3 dislike slightly
	2 mod. light	2 mod. mild	2 mod. soft/mushy	2 mod. unacceptable	2 dislike moderately
	1 very light	1 very mild	1 very soft/mushy	1 very unacceptable	1 dislike extremely

Figure 6. Sample form of questionnaire presented to untrained panel to evaluate color, flavor, texture, acceptability, and preference of canned plums

10. Statistical analyses

Means and standard deviations were computed for all data. One way analysis of variance and Tukey separations were performed according to Senter (1976), using a Texas Instruments SR-40 electronic calculator.

RESULTS AND DISCUSSION

1. Analysis of Whey and Its Products

Uncolored Cheddar cheese whey and its by-product ultrafiltered whey permeate (deproteinated whey) were analyzed for total solids, total protein, ash and pH (Table 3). Mean values for total solids, protein, ash and pH in the whey were 6.57%, 0.70%, 0.60% and 6.15 respectively. Upon fractionation in the UF system, the permeate retained 5.69% solids, 0.15% protein, 0.54% ash and a pH of 6.13. By calculation it can be seen that the permeate retained 83% of the total solids, 21% of the protein, and 90% of the ash while the pH value was about the same as that of whey. It was observed that the composition of the whey was similar to that reported by numerous other workers. The ultrafiltered whey permeate was similar in composition to that reported by Khorshid (1974).

2. Navy Beans

The typical composition of canned navy beans (solid bean and bean sauce) treated with permeate brine or lactose hydrolyzed permeate brine, is compared with that of untreated control in Table 4. The levels of total solids and ash (solid bean) in treated samples ranged from 35.27-

Table 3. Typical composition of uncolored cheddar cheese whey and UF permeate*

Trial	Total Solids, %		Total Protein, %		Ash, %		pH	
	Whey	Permeate	Whey	Permeate	Whey	Permeate	Whey	Permeate
A	6.58	5.69	0.69	0.15	0.59	0.54	5.92	6.15
B	6.54	5.71	0.71	0.17	0.60	0.54	6.12	6.12
C	6.58	5.69	0.69	0.14	0.61	0.54	5.90	6.12
Mean	6.57	5.69	0.70	0.15	0.60	0.54	6.15	6.13

*The data for each trial are the averages of duplicate determinations for all parameters.

Table 4. Typical composition of navy beans (solid bean and bean juice), canned in whey permeate or lactose-hydrolyzed whey permeate, as compared to an untreated control

Brine Treatment	Total Solids %[1]	Ash %[1]	pH[2]	Drained[2] wt. (g)
		solid bean		
Permeate	35.58±0.02b[3]	4.11±0.01b	-	340.8±0.02a
Lactose-hydrolyzed-permeate	35.27±0.01b	4.26±0.02b	-	341.2±0.01a
Control (untreated)	32.74±0.01a	3.99±0.04a	-	340.8±0.01a
		bean sauce		
Permeate	15.21±0.05b	10.24±0.01b	5.65±0.01a	-
Lactose-hydrolyzed-permeate	15.86±0.03b	10.91±0.04b	5.60±0.01a	-
Control (untreated)	14.16±0.04a	8.34±0.03a	5.60±0.01a	-

[1]Mean values for 3 cans x 2 samples/can, N = 6

[2]Mean values for 3 cans

[3]Like letters within columns denote no significant difference ($p \leq 0.01$).

35.58%, and 4.11-4.26%, respectively. A significant difference between all permeate treated samples (permeate and lactose hydrolyzed permeate) and the untreated sample (control) was detected for total solids and ash. The permeate treated samples contained a significantly higher level of both solids and ash. This difference can be attributed to the permeate and lactose-hydrolyzed permeate brines having a higher solids and ash content than the untreated brine. The bean sauce obtained from treated samples averaged 15.21-15.86% solids and 10.24-10.91% ash. As in the case of the solid beans, both permeate treated samples exhibited a significantly higher level of both solids and ash. Mean values for the drained weight and pH of the beans and sauce were 340.9 g and 5.62 respectively, indicating there was no difference between the 3 treatments for these parameters.

The ash and mineral content (P, Na, Ca and Mg) of the canned navy beans (solid bean and bean sauce) is shown in Table 5. Higher levels of ash and of most elements were observed in the samples treated with permeate and lactose-hydrolyzed permeate. Calcium levels in the treated solid bean samples were about 80% greater than the untreated control. Other elements, P (9.5%), Na (4.0%), and Mg (47%) also were at higher levels than the untreated control. Treated bean sauce samples also had higher levels of all elements analyzed. Phosphorous (24%), sodium (5%),

Table 5. Ash content and elemental analysis of treated navy beans (solid bean and bean sauce), canned in permeates compared with untreated (control) samples[1]

Treatment	Ash[2] (%)	P[2]	Na[2]	Ca[2]	Mg[2]
			mg/100 g		
			solid bean		
Permeate	4.11±0.45b	160.26±0.49b	395.32±0.37b	87.95±0.42b	60.00±0.46b
Lactose-hydrolyzed permeate	4.26±0.68b	164.77±0.66b	395.40±0.28b	91.05±0.74b	64.17±0.55b
Control (untreated)	3.99±0.42a	148.30±0.28a	380.50±0.77b	50.05±0.17a	42.05±0.42a
			bean sauce		
Permeate	10.24±0.77b	347.42±0.45b	549.20±0.84b	132.38±0.44b	147.66±0.75b
Lactose-hydrolyzed permeate	10.91±0.42b	355.10±0.77b	553.20±0.51b	157.41±0.88b	149.32±0.36b
Control (untreated)	8.34±0.33a	283.48±0.63a	525.36±0.38b	98.55±0.31b	125.45±0.42a

[1]Like letters within columns denote no significant difference

[2]Mean values for 1 can/treatment x 2 samples/can, N=2

calcium (58%) and magnesium (18%) levels were generally greater in the treated samples than in the untreated control. Because ultrafiltered whey permeate contains a rather high ash content, approximately 8-9% ash on a dry weight basis (Khorshid, 1974), this may account for the higher mineral content in the treated samples.

Kramer Shear, Hunter Color and mean sensory preference scores are shown in Table 6. Kramer Shear results were obtained from two peaks of bean deformation. The first peak shows the amount of force required for the proving ring to compress the bean's outer layer before it ruptures. The second peak is the force needed for the proving ring to compress and shear the inside of the bean. It can be seen from Table 6 that the permeate and lactose hydrolyzed samples required a significantly greater amount of force (1.69 and 1.75, respectively) to rupture the bean's outer layer. The amount of force required to shear the bean inside was also significantly greater for the treated samples, with permeate needing 2.12 lb/g, lactose-hydrolyzed permeate 2.29 lb/g, and the untreated control 1.51 lb/g. Significantly higher ash levels, especially Ca, are probably responsible for the greater degree of firmness in the treated samples.

Mean color coordinate values for navy beans (Table 6) show that there was a significant difference between treated and untreated beans in 2 of the 3 coordinate

Table 6. Mean shear compression force, color coordinate, and preference scores with Tukey separations for navy beans ($p \leq 0.01$)[1]

Treatment	Kramer Shear	
	lb/g	
	1st Pk	2nd Pk
Permeate	1.69±0.02b	2.12±0.03b
Lactose-hydrolyzed permeate	1.75±0.05b	2.29±0.04b
Control (untreated)	1.20±0.04a	1.51±0.03a
	Hunter Color Coordinate Values	
	L	a_L
Permeate	50.42±0.72a	6.86±0.62b
Lactose-hydrolyzed permeate	49.85±0.85a	6.60±0.70b
Control (untreated)	49.82±0.46a	1.99±0.45a
	Preference Scores[2]	
Permeate	3.32±0.76b	
Lactose-hydrolyzed permeate	3.36±0.72b	
Control (untreated)	4.70±1.78a	
Commercial sample	4.52±1.63a	

[1] Like letters within columns denote no significant difference

[2] 1=dislike extremely, 2=dislike moderately, 3=dislike slightly, 4=niether like nor dislike, 5=like slightly, 6=like moderately, 7=like extremely.

values. It was observed that while L values were similar (49.82-50.42), both treated samples had higher $+a_L$ values (6.62-6.86) and $+b_L$ values (18.30-18.70), than untreated samples ($+a_L$ = 1.99, $+b_L$ = 14.72). This shows that the treated beans had a significantly greater degree of redness ($+a_L$ value), as well as yellow color ($+b_L$ value).

Triangle difference testing for the navy beans demonstrated that the panelists were able to distinguish the odd sample (28/30 correct decisions). Overall preference testing (Table 6) showed significantly higher mean scores for both the untreated control and a commercial brand. Mean scores were 4.70 for the control, 4.52 for the commercial sample, 3.32 for the permeate and 3.36 for the lactose-hydrolyzed permeate. Thus, control and commercial samples were judged between neither like/dislike and like slightly. All permeate treated samples were judged between dislike slightly and neither like/dislike. In general, all permeate treated samples were deemed less desirable than control and commercial samples.

3. Kidney Beans

Canned kidney beans (solid bean and bean sauce) treated with permeate brine or lactose-hydrolyzed permeate brine were compared with the untreated control for their composition (Table 7). Mean values for the total solids and ash (solid bean) ranged from 32.63-39.75%, and 1.07-1.24%, respectively. The treated samples contained a significantly

Table 7. Typical composition of kidney beans (solid bean and bean sauce), treated with whey permeate or lactose hydrolyzed whey permeate, as compared to an untreated control

Brine Treatment	Total solids %[1]	Ash %[1]	Drained[2] wt.(g)	pH[2]
		solid bean		
Permeate	38.98±0.02b[3]	1.08±0.01b	338.4±0.02a	-
Lactose-hydrolyzed-permeate	39.75±0.04b	1.24±0.02a	339.5±0.02a	-
Control (untreated)	32.63±0.03a	1.07±0.01b	339.2±0.01a	-
		bean sauce		
Permeate	17.56±0.03b	15.11±0.05b	-	5.62±0.01a
Lactose-hydrolyzed permeate	19.55±0.04b	15.67±0.04b	-	5.60±0.01a
Control (untreated)	9.92±0.04a	14.16±0.02a	-	5.65±0.02a

[1]Mean values for 3 cans X 2 samples/can, N=6

[2]Mean values for 3 cans

[3]Like letters within columns denote no significant difference ($p \leq 0.01$)

higher level of both solids and ash. The bean sauce averaged 9.92-19.55% solids and 14.16-15.69% ash. Both treated bean sauce samples had significantly greater levels of solids and ash. As in the case of the navy beans, this is probably caused by the permeate having rather high solids and ash contents. On the average, drained weight and pH of the beans and sauce were 339.0 and 5.62 respectively. The treatments were similar to control for these parameters.

The ash and mineral content (P, Na, Ca and Mg) of the canned kidney beans (solid bean and bean sauce) is shown in Table 8. Higher levels of ash and of most elements was observed in the samples treated with permeate and lactose hydrolyzed permeate. Calcium levels in the treated solid bean samples were 2-fold greater than the untreated control. Phosphorous, sodium and magnesium levels were observed to be similar to that of the untreated control. Kidney bean sauce levels of P, Na, Ca and Mg were increased by 22, 8, 13 and 75% respectively, in relation to the juice obtained from untreated (control) samples.

Kramer Shear, Hunter Color and mean preference scores are shown in Table 9. Kramer Shear results show a significant difference between treated and untreated samples. Permeate brined beans (2.16 lb/g) and lactose-hydrolyzed permeate brined beans (2.60 lb/g), were significantly firmer than untreated beans (1.46 lb/g). This increased

Table 8. Ash contents and elemental analysis of treated kidney beans (solid bean and bean sauce), canned in permeates compared with untreated (control) samples[1]

Treatment	Ash[2] (%)	P[2]	Na[2]	Ca[2]	Mg[2]
			mg/100 g		
			solid bean		
Permeate	1.08±0.17a	292.41±0.45a	26.79±0.25a	222.15±0.30b	135.11±0.45a
Lactose-hydrolyzed permeate	1.24±0.17a	283.12±0.62a	28.85±0.41a	283.10±0.45b	135.06±0.33a
Control (untreated)	1.07±0.20a	301.38±0.77a	20.77±0.88a	108.35±0.27a	134.50±0.77a
			bean sauce		
Permeate	14.71±0.24b	598.92±0.37b	150.53±0.75b	304.15±0.66b	68.32±0.44b
Lactose-hydrolyzed permeate	15.67±0.33b	627.20±0.46b	154.21±0.86b	309.86±0.54b	69.40±0.27b
Control (untreated)	14.15±0.41a	503.20±0.25a	141.45±0.77a	271.67±0.21a	39.22±0.42a

[1]Like letters within columns denote no significant difference.

[2]Mean values for 1 can/treatment x 2 samples/can, N=2

Table 9. Mean shear compression force, color coordinate, and preference scores with Tukey separations for kidney beans ($p \leq 0.01$)[1]

Treatment	Kramer Shear		
	lb/g		
Permeate	2.16±0.15b		
Lactose hydrolyzed permeate	2.60±0.20b		
Control (untreated)	1.46±0.12a		
	Hunter Color Coordinate Values		
	L	a_L	b_L
Permeate	28.41±0.65b	10.70±0.24a	8.30±0.42a
Lactose hydrolyzed permeate	28.83±0.77b	10.85±0.77a	8.15±0.78a
Control (untreated)	26.52±0.38a	10.70±0.65a	7.95±0.42a
	Preference Scores[2]		
Permeate	2.40±0.68b		
Lactose hydrolyzed permeate	2.00±0.73b		
Control (untreated)	3.45±1.02a		
Commercial sample	3.26±0.82a		

[1] Like letters within columns denote no significant difference.

[2] 1=dislike extremely, 2=dislike moderately, 3=dislike slightly, 4=neither like nor dislike, 5=like slightly, 6=like moderately, 7=like extremely

firmness level in the treated beans can also be attributed to a rather high ash content, especially the calcium level (Table 8) of the permeate.

Mean color coordinate values for kidney beans (Table 9), show $+a_L$ coordinate values ranging from 10.70-10.85, $+b_L$ values from 7.95-8.30, and L values from 26.5-28.8. Hunter $+a_L$ and $+b_L$ values for all three treatments were similar. Both treated samples were observed to have significantly different L values than the untreated control. The higher L values for the treated samples indicate that those kidney beans were lighter in color than the control beans.

Overall preference testing (Table 9) showed significantly higher mean scores for both the untreated control and a commercial sample. Mean scores were 3.45 for the control, 3.26 for the commercial sample, 2.40 for the permeate, and 2.00 for the lactose-hydrolyzed permeate. Thus, control and commercial samples were judged between dislike slightly and neither like/dislike. All permeate treated samples were judged between dislike moderately and dislike slightly. Twenty-three percent of the panelists indicated that the treated beans were firmer. In general, all samples were deemed something less than desirable.

4. Plums

The typical composition of canned plums (solid plum and plum syrup) treated with sucrose replacement levels of 5, 10, 15, 20 and 25% lactose-hydrolyzed permeate (HP), or crystalline glucose-galactose (GG), as compared to an

untreated control is shown in Tables 10 and 11. It can be seen from the Table that the total solids (27.5%) and ash (0.48-0.49%) for the solid plums were similar in composition. Drained weight values (284.5 g) were also similar. Plum syrup composition is shown in Table 11. Total solids for all plum syrup samples ranged from 12.46-12.49%, and ash contents ranged from 0.10-0.11%. Values for plum syrup pH ranged from 3.58-3.62, with one exception, that of 25% GG replacement with a pH of 3.34.

The ash and mineral contents of the canned plums (solid plum and plum syrup) are shown in Table 12. Generally, higher levels of P, Na, Ca and Mg were observed in the HP samples of the solid plums than in the control and GG samples. HP samples had phosphorous levels of 3.19-3.32 mg/100 g, Na (11.66-12.82 mg/100 g), Ca (11.35-12.43 mg/100 g) and Mg levels from 5.21-6.14 mg/100 g. Control plums had levels of 3.05 mg/100 g for P, 11.12 mg/100 g for Na, 11.04 mg/100 g for Ca, and 5.10 mg/100 g for Mg. Plum syrup samples had similar overall results to those found in the solid plums. Thus, generally the HP syrup had higher levels of P, Na, Ca and Mg than the control and GG samples. HP samples had phosphorous levels ranging from 10.26-10.42 mg/100 g, sodium levels from 1.17-1.30 mg/100 g, calcium levels from 9.01-9.05 mg/100 g, and magnesium ranging from 3.97-4.05 mg/100 g. Control plum syrup had levels of 10.15 mg/100 g for phosphorous, 1.01 mg/100 g for

Table 10. Typical composition of canned plums (solid plum), treated with sucrose replacement levels of 5, 10, 15, 20, 25% hydrolyzed whey permeate (HP) or crystalline glucose-galactose (GG), as compared to an untreated control.[1]

Treatment	Total[2] Solids %	Ash[2] %	Drained[3] wt.
Control	27.53±0.03a	0.49±0.01a	284.5±0.04a
5% HP	27.53±0.02a	0.49±0.04a	284.5±0.04a
10% HP	27.54±0.02a	0.49±0.02a	285.0±0.03a
15% HP	27.52±0.02a	0.49±0.01a	285.0±0.04a
20% HP	27.51±0.04a	0.49±0.01a	284.2±0.04a
25% HP	27.51±0.03a	0.49±0.01a	274.0±0.04a
5% GG	27.53±0.02a	0.29±0.02a	284.5±0.03a
10% GG	27.53±0.01a	0.29±0.01a	285.0±0.02a
15% GG	27.54±0.01a	0.29±0.02a	284.2±0.02a
20% GG	27.52±0.04a	0.29±0.02a	284.5±0.02a
25% GG	27.54±0.05a	0.28±0.02a	284.0±0.03a

[1]Like letters within columns denote no significant difference.

[2]Mean values of 2 cans x 3 samples/can, N=6

[3]Mean values of two cans

Table 11. Typical composition of canned plums (plum syrup), treated with sucrose replacement levels of 5, 10, 15, 20, 25% hydrolyzed whey permeate (HP), or crystalline glucose-galactose (GG), as compared to an untreated control[1]

Treatment	Total[2] Solids %	Ash[2] %	pH[3]
Control	12.47±0.04a	0.10±0.01a	3.60±0.03a
5% HP	12.47±0.04a	0.11±0.01a	3.59±0.04a
10% HP	12.48±0.03a	0.11±0.02a	3.60±0.05a
15% HP	12.48±0.04a	0.11±0.01a	3.60±0.02a
20% HP	12.48±0.04a	0.11±0.01a	3.58±0.03a
25% HP	12.49±0.03a	0.11±0.01a	3.59±0.02a
5% GG	12.47±0.03a	0.10±0.01a	3.61±0.03a
10% GG	12.47±0.03a	0.10±0.02a	3.60±0.02a
15% GG	12.47±0.02a	0.10±0.01a	3.60±0.03a
20% GG	12.46±0.03a	0.10±0.02a	3.62±0.03a
25% GG	12.46±0.03a	0.10±0.01a	3.34±0.02b

[1] Like letters within columns denote no significant difference

[2] Mean values of 2 cans x 3 samples/can, N=6

[3] Mean values of two cans

Table 12. Ash content and elemental analysis of untreated (control) plums (solid and syrup), compared with treated samples[1]

Treatment	Ash[2] %	P[2]	Na[2]	Ca[2]	Mg[2]
			mg/100 g		
			solid plum		
Control	0.4891±0.03a	3.05±0.07a	11.12±0.44a	11.04±0.65a	5.10±0.21a
5% HP	0.4904±0.03a	3.19±0.11b	11.66±0.63b	11.35±0.41b	5.21±0.48a
10% HP	0.4919±0.02a	3.25±0.14b	12.03±0.36b	11.81±0.38b	5.46±0.36b
15% HP	0.4917±0.04a	3.30±0.09b	12.24±0.72b	11.98±0.29b	5.20±0.21a
20% HP	0.4923±0.03a	3.32±0.06b	12.67±0.25b	12.31±0.75b	5.99±0.78b
25% HP	0.4930±0.03a	3.30±0.10b	12.82±0.44b	12.42±0.80b	6.14±0.23b
5% GG	0.4882±0.03a	3.02±0.15a	11.17±0.81a	11.00±0.62a	5.12±0.44a
10% GG	0.4888±0.03a	3.00±0.07a	11.16±0.72a	11.10±0.55a	5.14±0.36a
15% GG	0.4895±0.03a	3.03±0.11a	11.10±0.35a	11.08±0.75a	5.10±0.50a
20% GG	0.4985±0.04a	3.05±0.09a	11.21±0.25v	11.05±0.66a	5.08±0.50a
25% GG	0.4801±0.04a	3.05±0.07a	11.23±0.72a	11.05±0.41a	5.11±0.44a
			plum syrup		
Control	0.1010±0.02a	10.15±0.17a	1.01±0.14a	8.80±0.19a	3.96±0.08a
5% HP	0.1112±0.02a	10.26±0.20b	1.17±0.21b	9.01±0.22b	3.97±0.07a
10% HP	0.1123±0.03a	10.28±0.20b	1.22±0.11b	9.01±0.15b	4.00±0.07a
15% HP	0.1133±0.03a	10.29±0.11b	1.24±0.30b	9.02±0.35b	4.05±0.04a
20% HP	0.1146±0.03a	10.38±0.15b	1.29±0.17b	9.05±0.15b	4.02±0.06a
25% HP	0.1160±0.04a	10.42±0.25b	1.30±0.27b	9.05±0.20b	4.01±0.07a
5% GG	0.1011±0.02a	10.11±0.17a	0.99±0.11a	8.75±0.20a	4.00±0.06a
10% GG	0.1012±0.04a	10.12±0.11a	1.02±0.24a	8.77±0.15a	4.02±0.04a
15% GG	0.1012±0.04a	10.05±0.25a	1.02±0.17a	8.83±0.26a	3.95±0.05a
20% GG	0.1016±0.03a	10.08±0.15a	1.02±0.30a	8.80±0.20a	4.06±0.08a
25% GG	0.1019±0.02a	10.12±0.15a	1.01±0.14a	8.81±0.35a	4.02±0.05a

[1]Like letters within columns denote no significant difference

[2]Mean values for 1 can/treatment x 4 samples/can, N=4

sodium, 8.80 mg/100 g calcium and 3.96 mg/100 g for magnesium. GG samples had values of 10.05-10.12 mg/100 g phosphorous, 0.99-1.02 mg/100 g sodium, 8.75-8.83 mg/100 g, and 3.95-4.06 mg/100 g magnesium. It may be concluded that all permeate-containing samples had comparable levels of ash and minerals.

Kramer Shear and Hunter Color mean values are shown in Table 13. Mean Kramer Shear values for all 3 treatments were similar, ranging from 0.98-1.05 lb/g force product. Part of the reason for this was that the plums prior to canning had been frozen, causing some textural (cellular) damage. Color coordinate values (also in Table 13) for the solid plums had $+a_L$ values ranging from 8.75-9.10 for all 3 treatments. Twenty five percent GG had a $+b_L$ value of 4.25, which was significantly higher than all of the other values (2.80-3.10). Control and GG plums had L values that were significantly higher (17.45-17.65) than HP plums (12.45-12.90). Generally, these data show that the HP plums were lighter in color, and that the 25% GG plums had a greater amount of yellow in them. Plum syrup color values show that HP treated plums had L, $+a_L$, and $+b_L$ values of 7.80-8.25, 6.60-6.90, and 1.05-1.15, respectively. These three values were significantly higher than either the control (3.52 L, 5.20 a_L, 0.45 b_L), or GG (3.35-3.60 L, 5.22-5.45 a_L, 0.40-0.50 b_L) samples, indicating that the HP plum syrup had greater white, red, and yellow

Table 13. Mean shear compression force and color coordinate values with Tukey separations for canned plums ($P \leq 0.01$)[1]

Treatment[2]	Kramer Shear	Hunter Color Coordinate Values					
		Solid Plum			Plum Syrup		
	lb/g	L	a_L	b_L	L	a_L	b_L
Control (untreated)	0.98±0.02a	17.50±0.21b	8.75±0.14a	3.10±0.08a	3.52±0.33b	5.20±0.19b	0.45±0.11b
5% HP	0.98±0.02a	12.90±0.15a	8.95±0.20a	2.80±0.10a	8.15±0.42a	6.75±0.24a	1.05±0.20a
10% HP	1.05±0.01a	12.85±0.18a	9.05±0.24a	2.95±0.11a	7.80±0.61a	6.60±0.20a	1.15±0.15a
15% HP	1.02±0.04a	12.90±0.33a	8.90±0.10a	3.00±0.09a	8.20±0.65a	6.90±0.20a	1.12±0.32a
20% HP	1.10±0.04a	12.50±0.22a	9.10±0.16a	3.00±0.06a	8.25±0.44a	6.85±0.35a	1.10±0.15a
25% HP	1.05±0.02a	12.45±0.17a	8.95±0.27a	3.00±0.07a	8.05±0.33a	6.85±0.38a	1.15±0.20a
5% GG	1.00±0.03a	17.45±0.21b	8.80±0.31a	2.90±0.11a	3.40±0.32b	5.35±0.17b	0.50±0.04b
10% GG	1.00±0.02a	17.50±0.43b	8.80±0.14a	2.85±0.09a	3.35±0.42b	5.22±0.20b	0.40±0.06b
15% GG	1.02±0.01a	17.65±0.15b	8.80±0.10a	3.12±0.10a	3.52±0.50b	5.50±0.26b	0.40±0.07b
20% GG	1.02±0.04a	17.50±0.23b	8.80±0.22a	3.00±0.14a	3.60±0.26b	5.45±0.20b	0.50±0.07b
25% GG	1.00±0.02a	17.45±0.17b	8.60±0.24a	4.25±0.18b	4.30±0.77c	4.00±0.15c	0.50±0.03b

[1]Similar letters within columns denote no significant difference

[2]Mean values of 1 can x 3 samples/can, N = 3

values. Plum syrup at 25% GG had L (4.30) and $+a_L$ (4.00) values that were significantly different than all of the other samples. Thus, this particular plum syrup was less red than all the others, and lighter in color than the control but darker than the HP plum syrup.

Color, flavor, texture, general acceptability and overall preference mean values are shown in Table 14. Color scores for 5, 15 and 25% HP were 5.12, 5.03, and 5.27, respectively. Control, 5 and 15% GG had mean color scores ranging from 4.16-4.22, and plums at 25% GG had a score of 3.37. It can be seen that the HP plums were rated significantly higher (darker) than the control, 5 and 15% GG, which in turn were rated significantly higher than 25% GG for color. Flavor mean values for control, 5, 15, and 25% HP and 5% GG ranged from 3.96-4.26, with 15 and 25% GG having scores of 5.58 and 5.33. This shows that the 15 and 25% GG plums were considered by the panelists to have a stronger flavor, while the other treatments were considered more mild. Textural scores for all treatments were similar, ranging from 3.04-3.60. Acceptability scores for all plum treatments (6.37-6.63), except 25% GG (4.05), were similar. Overall preference ratings for the control, 5, 15, 25% HP and 5% GG plums ranged from 5.12 to 5.40. Plums at 15 and 25% GG had significantly lower preference scores of 4.05 and 3.97. In general, plums canned in permeate containing syrups were quite acceptable (judged

Table 14. Mean color, flavor, texture, general acceptability and overall preference with Tukey separations for sucrose replacement HP and GG plums, as compared to an untreated control ($p \leq 0.01$)

Treatment	Color[1]	Flavor[2]	Texture[3]	General Acceptability[4]	Overall Preference[5]
Control	4.22±0.54a[6]	4.04±0.97a	3.32±0.63a	6.44±0.50a	5.40±0.41a
5% HP	5.12±0.78b	4.10±0.73a	3.18±0.55a	6.49±0.73a	5.42±0.69a
15% HP	5.03±0.73b	4.26±0.55a	3.60±0.73a	6.63±0.55a	5.34±0.43a
25% HP	5.27±0.80b	3.96±0.53a	3.21±0.66a	6.45±0.63a	5.12±0.31a
5% GG	4.21±0.53a	4.12±0.38a	3.25±0.72a	6.21±0.97a	5.28±0.55a
15% GG	4.16±0.69a	5.58±0.73b	3.04±0.83a	6.37±0.73a	4.05±0.54a
25% GG	3.37±0.97c	5.33±0.81b	3.45±0.80a	4.05±0.55b	3.97±0.38b

[1] 1=very light, 2=mod. light, 3=slt. light, 4=neither dark/light, 5=slt. dark, 6=mod. dark, 7=very dark

[2] 1=very mild, 2=mod. mild, 3=slt. mild, 4=neither strong/mild, 5=slt. strong, 6=mod. strong, 7=very strong

[3] 1=very soft/mushy, 2=mod. soft/mushy, 3=slt. soft/mushy, 4=neither firm/soft, 5=slt. firm/dense, 6=mod. firm/dense, 7=very firm/dense

[4] 1=very unaccept., 2=mod. unaccept., 3=slt. unaccept., 4=neither accept./unaccept., 5=slt. accept., 6=mod. accept., 7=very accept.

[5] 1=dislike extrem., 2=dislike mod., 3=dislike slt., 4=neither like/dislike, 5=like slt., 6=like mod., 7=like extremely

[6] Like letters within columns denote no significant difference

between like slightly and like moderately).

SUMMARY AND DISCUSSION

In summary, navy and kidney beans were hydrated in water, then canned in appropriate brines: control, permeate, and lactose hydrolyzed permeate. Analyses of color, texture, total solids, ash and sensory preference were subsequently performed. The following were the findings:

1. Beans processed with whey permeate were significantly firmer than control samples. Firming action may be due to increased levels of Ca and Mg cations which form firm metal-pectin complexes within the cellular matrix of the bean.

2. Beans processed with whey permeate were generally darker in appearance than control samples. Hunter $+a_L$ (increased redness) and $+b_L$ (increased yellowness) values increased in all permeate treated samples. White navy beans showed a greater color difference from control samples than did dark kidney type beans. Darkening may be due to greater oxidation due to permeate minerals, or due to increased Maillard type browning. It appears likely that the off color may be readily masked in a tomato based sauce.

3. Increased total solids and particularly increased mineral content are delivered through the use of whey permeate which may have a beneficial nutritional value and serve as a means of economic utilization of whey permeate.

4. Hedonic sensory ratings for navy and kidney beans canned with whey permeate were significantly lower than control samples or a commercial check sample.

Plums were canned in a control sugar syrup, and in 5, 10, 15, 20, 25% sucrose replacements of lactose hydrolyzed permeate (HP) or crystalline glucose-galactose (GG). The following were the findings:

1. Plums processed with whey permeate were not significantly firmer than control samples.

2. Plums (both solid and syrup) processed with lactose hydrolyzed permeate were generally darker in appearance than control or GG samples. Hunter L values were lower (darker, blacker) in HP samples than control or GG samples. The darkening may be due to greater oxidation due to permeate minerals.

3. Total solids and particularly increased mineral content are delivered through the use of whey permeate which may enhance nutritional value, reduce calories, and serve as a means of economic utilization of whey permeate.

4. Hedonic sensory ratings for plums canned in permeate containing syrups were not significantly lower than control samples. In fact, HP plums were judged quite

acceptable.

In conclusion, this work demonstrates that processing foods with whey permeate is feasible. However further work is required to optimize formulations and applications.

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