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A HORCHATA-TYPE BEVERAGE FROM A WHEY/RICE SOLIDS BLEND

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A HORCHATA-TYPE BEVERAGE FROM
A WHEY/RICE SOLIDS BLEND

by

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This thesis is dedicated to my parents, Luis and Alicia Camou, whose constant emotional support has given me the strength and opportunity to realize my dreams, and, without whom, none of this would be possible.

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ABSTRACT

The purpose of this study was to formulate a nutritious, acceptable beverage in order to provide an alternative solution to whey disposal. Two high quality, economical protein sources, cottage cheese whey and puffed rice, were used as the main ingredients in a 3 X 2 factorial design that resulted in 8 mix formulations with varying concentrations of whey and rice. These beverages were subjected to chemical analysis, and presented to a 52 member untrained panel for evaluation of sensory attributes as rated on a 9-point hedonic scale.

Results of the analyses showed that the compositions of the beverages were within expected ranges. In addition, the essential amino acid patterns of the beverages showed that they had high quality protein when compared to the Food and Agriculture Organization (FAO) recommended pattern.

In the sensory evaluation, panelists preferred lower concentrations of rice and whey over all other beverage formulations. In addition, they preferred higher concentrations of whey over higher concentrations of rice. However, intra-attribute correlations suggested that the panelists' ratings of the attributes may have been strongly influenced by the flavor of the beverages. Thus, although the overall acceptability ratings of the beverages were at the mid-range of the hedonic scale, the nutritional quality of all the beverages was comparatively high, and the beverages provide an alternative to nutrient loss in the case of whey disposal as industrial waste.

CHAPTER 1

INTRODUCTION

Approximately nine kilograms of cheese are produced from each 100 kilograms of milk. During cheese manufacturing, curd is formed by bacterial fermentation to produce acid, by direct acidification, or by the use of the enzyme rennin. In natural acidification, microorganisms utilize the lactose in the milk. This action converts the lactose to lactic acid and lowers the pH of the milk thus causing the casein to precipitate at its isoelectric point. In direct acidification, instead of utilizing microorganisms, an acid is added to speed the process and to minimize the time and attention required for coagulation by microorganisms. This process (direct acid set method) also lowers the pH of the milk and causes the casein to precipitate. The third process uses the proteolytic enzyme rennin. When adding rennin to milk, the casein coagulates by breaking down the K-casein coat that protects the micelle from insolubilization by calcium ions (de Man, 1980).

The liquid that separates after coagulation of casein in cheese manufacturing is a by-product referred to as whey. The whey obtained by direct acidification or by the procedure in which a significant amount of lactose is converted to lactic acid (i.e., the action of microorganisms) is referred to as acid whey, and the whey that is obtained by rennin coagulation is referred to as sweet whey. In their review, Cosidine and

Cosidine (1982) report that sweet whey contains more total solids (6.5% vs. 5.2%), more lactose (4.9% vs. 4.3%), more protein (0.8% vs. 0.6%), and a higher ash content (0.56% vs. 0.46%) than acid whey. Acid whey contains more lactic acid than sweet whey (0.7% to 0.8% vs. 0.1% to 0.2%). In addition, according to Kosikowski (1979), acid whey has a lower pH (4.4 to 4.6) than sweet whey (5.9 to 6.3).

The whey that results from cheese manufacturing retains about 55% of the milk nutrients. About 54% is retained by sweet whey and about 74% is retained by acid whey (Kosikowski, 1967). Thus, whey is a rich source of nutrients that varies according to its composition (Table 1), and contains a very high number of amino acids that are vital for man (Werner, 1981). These amino acids (Table 2) and the essential amino acid content of whey protein compared to the Food and Agriculture Organization (FAO) recommended pattern (Table 3) are of interest. Kosikowski (1967) reports that whey also contains large quantities of calcium, lactose, and water soluble vitamins.

Although whey protein concentration is comparatively lower (approximately 0.6%) than other protein sources (Cuddy & Zall, 1982), its percentage of protein increases as the amount of water is decreased. For example, the percentage of total protein found in fluid whey is 0.8% compared to 13.1% total protein found in dried sweet whey (Table 1). Whey proteins consist principally of α-lactoglobulin, β-lactoglobulin, immunogobulins, serum albumin, and minor proteins (Fennema, 1976). In addition, the Protein Efficiency Ratio (PER) of whey is very high ranging from 3.2 to 3.4 (Cuddy & Zall, 1982).

Table 1. Composition of fluid whey and whey products.[a]

Component	Fluid Sweet Whey	Fluid Acid Whey	Dried Sweet Whey	Dried Acid Whey
	%			
Moisture	93.12	93.42	2.19	3.51
Carbohydrates	5.14	5.12	74.46	73.45
Total Protein	0.85	0.76	12.93	11.73
Fat	0.36	0.09	1.07	0.54
Ash	0.53	0.61	8.35	10.77
Total Solids	6.88	6.58	97.81	96.49

[a] U.S. Department of Agriculture (1976).

Table 2. Amino acids in fluid whey.

Amino Acids	Amount in 100g, edible portion	Amount in edible portion of common measures of food 1 c = 246g	1 qt = 984g	Amount in edible portion of 1 pound of food as purchased
	GRAMS			
Tryptophan	.016	.038	.154	.071
Threonine	.038	.094	.376	.173
Isoleucine	.038	.093	.370	.171
Leucine	.072	.178	.712	.328
Lysine	.065	.161	.642	.296
Methionine	.014	.035	.141	.065
Cystine	.014	.034	.135	.062
Phenylalanine	.025	.062	.246	.113
Tyrosine	.019	.048	.191	.088
Valine	.038	.092	.369	.170
Arginine	.021	.052	.209	.096
Histidine	.015	.037	.147	.068
Alanine	.033	.081	.322	.149
Aspartic acid	.074	.183	.733	.338
Glutamic acid	.136	.334	1.336	.616
Glycine	.014	.034	.135	.062
Proline	.015	.111	.445	.205
Serine	.035	.086	.345	.159

Table 3. Essential amino acid content of whey proteins[a] as compared to the Food and Agriculture Organization (FAO) pattern.

Amino Acid	Sweet Whey Protein	Acid Whey Protein	FAO Protein
		g/100 g	
Leucine	10.3	10.3	4.8
Lysine	8.8	10.3	4.2
Threonine	6.8	4.9	2.8
Isoleucine	5.9	5.4	4.2
Valine	5.9	5.2	4.2
Phenylalanine	3.5	3.7	2.8
Tryptophan	2.4	2.4	1.4
Methionine	1.8	1.8	2.2

a Values taken from Table 2.

It has been estimated that the annual worldwide production of cheese by the late 1970s (Table 4) exceeded 11,699 X 1000 metric tons, and the United States contributed more than 1943 X 1000 metric tons to this total (Cosidine & Cosidine, 1982). Interestingly, Giles (1974) reported that the annual production of cheese in the United States resulted in 9.9 billion kilograms of fluid whey in 1974; an amount that approximates the estimated worldwide production of cheese in 1982. Wagner (1981) reported that there was an increasing trend in total whey production in the United States from 1972 to 1979. In addition, DeMott et al. (1981) reported that, in the United States alone, the annual production of cheese was over 450 million kilograms, and that results in over 2.3 billion kilograms of acid whey. With these striking statistics on the large amounts of whey, the obvious question is what to do with the fluid whey that results from cheese production.

In the past, cheese production was limited to farms and small rural factories. The whey that resulted from these small scale operations was usually fed to livestock or scattered on fields for fertilization. However, as cheese production increased and became more commercialized, the amount of whey was in excess of what the farmers could use for feed or fertilization. Thus, whey utilization and disposal became problematic. Since the increases in whey could not be absorbed by animal feed supplements, the balance of the whey was discarded into nearby lakes and rivers or into sewage systems (Kosikowski, 1967; Allum, 1980; Blackburn & Bassett, 1982).

This alternative, however, did not eliminate the problem, but

Table 4. Trends in annual cheese production.

Period	Worldwide	United States
	Metric tons X 1000	
Early 1960	5934	1032
Mid 1970	9565	1593
Late 1970	11669	1943

rather tended to produce more serious problems. The organic nutrients in whey consume high quantities of oxygen during degradation. This biological oxygen demand (BOD) has been estimated at 30,000 to 60,000 ppm (Blackburn & Bassett, 1982). Thus, whey dumping causes pollution in lakes and rivers and places a burden on sewage systems. Current anti-pollution laws restrict the quantities of whey that are disposed of through these methods. For example, the 1972 Amendment to the Water Pollution Act will force dairy plants to restrict whey dumping in sewers by 1985 (Blackburn & Bassett, 1982). In part, these restrictions have been the impetus for greater concentration of whey utilization by manufacturers and researchers. Clearly, returning the whey to the human food chain would be a viable alternative to dumping. However, this has not met with great acceptance on the parts of manufacturers or consumers.

Several problems are associated with the utilization and processing of whey. In its liquid form, whey has a high concentration (up to 94%) of water (Allum, 1980). In this form, large amounts of liquid whey need to be ingested by humans to provide only a small amount of nutrients. In addition, liquid whey has not met with wide acceptance because of its acid taste (DeMott et al , 1981). Moreover, liquid whey is cumbersome to store or transport. The alternative is to remove the water to produce whey concentrates. Clearly, whey concentrates are easier to transport and they can be preserved for longer periods of time. In addition, should the production of dry skim milk (DSM) decline, the whey concentrates could serve as substitutes in certain foods (Holsinger et al., 1974b;

Allum, 1980). However, even with costs reduced by advanced technology, the price the manufacturers pay to produce the concentrates is higher than when whey is used in liquid form, and the return for concentrates frequently only covers the manufacturers' costs (Allum, 1980). As a result, manufacturers and researchers have proposed the utilization of whey as a base for many types of food for human consumption (Table 5). Thus, combinations of whey with other foods have been produced and marketed.

Because of their complimentary nutritive values, whey and rice can be combined to provide an excellent source of high quality protein. Rice is a cereal protein and, as such, is part of the family of cereals that contribute 60% of the world's total protein supply (Johnson et al., 1977). Similar to whey, the concentration of rice protein is very low, ranging from 7.5% to 8.1% (Wommack & Vaughan, 1972). However, research has shown that rice has a fairly well balanced protein, and the quality of rice protein (PER = 1.7 to 1.9) is higher than that of many other cereal proteins including wheat (PER = 1.5) and maize (PER = 1.2) (Bonzinni & Silano, 1978; Johnson et al., 1977; Lockhart & Nesheim, 1978).

As a complement, rice protein is low in lysine and threonine, but whey protein is high in lysine, threonine, tryptophan, and cysteine. Only phenylalanine and tyrosine are comparatively low in the whey protein. This would suggest that whey protein could supplement cereal protein (Forsum, 1975).

In addition, it has been shown that the PER of the cereal protein increases when whey has been mixed with cereals (Hernandez et al, 1982;

Table 5. Some uses for whey.

Beverages:	Fruit juices Deproteinized, carbonated ("Rivella") Cola drinks (pH = 4) Vegetable juices (tomato) Soups (cream of tomato)
Dairy Products:	Ice cream, sherbert, and popsicles Process cheese and cheese spreads Cream sauces Modified milk
Bakery Products:	Cakes, cookies, crackers Sour dough and rye bread Prepared mixes Breading mixes for fried foods Pie crust and fillings
Meat Products:	Meat loaves and spreads Sausages and frankfurters
Confections:	Fudge, caramel, fondants

Wommack & Vaughan, 1972). For example, Wommack and Vaughan (1972) found that when rice was supplemented with whey concentrate, the PER increased from 1.3 to 3.38. Also, Forsum (1975) calculated the nutritive value of rice protein supplemented with whey protein concentrate and found a chemical score greater than 100 for such blends.

The purpose of this study was to demonstrate the possibility of liquid whey utilization as an alternative to expensive whey processing or whey disposal in lakes, rivers, and sewers as industrial waste. Specifically, it was designed to utilize two sources of high quality protein and other nutritients by combining fluid cottage cheese whey with puffed rice to produce a whey-based beverage. The intent was to simulate the formula of a commonly used beverage in Mexico, called Horchata, that uses rice and milk as its principal base. Also, the overall acceptability and other properties of the beverage were examined.

CHAPTER 2

REVIEW OF LITERATURE

Whey

Whey Processing

Rather than having discrete methods, whey processing lies along a continuum from liquid form (no processing) through whey protein concentrate forms (limited processing) through dried or powdered forms (complete drying processing) depending on its intended use (Table 6). For example, whey protein concentrates can be processed by ultrafiltration methods. This process passes low molecular weight components (lactose, salts, and water) through an ultrafiltration membrane that retains the larger protein molecules (Moor, 1975). Because it yields an undenatured, soluble protein that has excellent functional and nutritional properties (Greig & Harris, 1983), the resultant whey is able to replace part of the liquid milk used in yogurt manufacturing.

An example of the drying process consists of applying the whey in a thin layer on the surface of a revolving heated drum. This process, called drum drying, allows the thin layer of whey to lose moisture through contact with the drum's heated surface (Potter, 1973). Although whey is sometimes dried by this process, typically, the drying application is for animal feed supplements because, to some degree, the product acquires a cooked flavor and color, and, thus, it is usually less acceptable by consumers for human consumption.

Table 6. Forms, processing methods and uses of whey.

Whey Type	Processing	Examples of Uses
	Neutralization	Beverages (e.g., juices, soups)
Liquid whey	Pasteurization	Confections (e.g., coatings on candy)
	Limited or no processing	Dairy (e.g., popsicles, cream sauces)
	Reverse osmosis	Dairy products (e.g., processed cheese)
	Ultrafiltration	Bakery products (e.g., breads, cakes)
Whey Protein Concentrates	Electrodyalysis	Meat products (e.g., meat loaves)
	Sephadex Gel Filtration	Confections (e.g., fudge, caramels)
	Metaphosophate Complex	
	Drum drying	Dairy products (e.g., cheese spreads)
Dry Whey	Freeze drying	Bakery products (e.g., bread, mixes)
	Heat coagulation	Emulsion stabilizers (e.g., mayonaise)
		Snack foods (e.g., wafers)

An example of the use of liquid whey, whereby it is not processed, can be found in a study by Stull et al. (1977). Liquid cottage cheese whey was used in the formulation of frozen novelties. Although no processing of whey was used, the results showed that the frozen novelties were as acceptable as the conventional products based on water formulation.

A primary consideration of whether whey is processed for human food consumption, animal feed supplements, or disposed of as waste is the economics of processing liquid whey (Jelen & LeMaguer, 1976). Clearly, the more intense the process, the more the costs increase. Nonetheless, research favors the use of whey utilization for man or animals over environmental pollution through disposing as waste.

Whey Utilization: General

With an estimated increase of cheese production at an annual rate of 3.9% (International Dairy Federation, 1982), several alternative methods to dumping the increased volume of whey in an effort to minimize pollution have been proposed. These include spray irrigation methods (Parkinof & Salmons, 1982), biofiltration methods (Feofanov, 1982), biological denitrification in aerated lagoon systems (Ishibashi, 1982), field fertilization and animal feed supplement methods (Modler, 1982), and human consumption methods (Allum, 1980). However, most of these methods have serious shortcomings. For example, spray irrigation and field fertilization methods saturate farmlands with nitrogen that, when oxygenated, yields excessive nitrates. These methods may result in major environmental hazards (Karnauska & Huttl, 1981). Biofiltration and biological denitrification methods have obvious increased costs that exclude their use by small manufacturers. In many cases, animal feed methods are limited because the costs of transporting, handling, and processing liquid whey exceed the costs of alternative feeds (Webb, 1975), and animal consumption cannot compete with the increases in production. Forms for human consumption have similar transportation and processing costs, but they have been the most widely accepted and researched methods (Holsinger, 1972; Hambraeus, 1978; Allum, 1980) because the price return is usually greater. To date, the majority of research has been concerned with the inclusion of whey in foods and beverages (see Mann, 1982 for review).

Whey Utilization in Food

The major component of whey is lactose. Although the uses of lactose are increasing (Holsinger, 1979), the use of this sugar for human consumption remains low, in part because lactose is slowly digested and absorbed from the intestine (Wagner, 1981), and because approximately 70% of the world's adult population is lactose intolerant (Holsinger, 1978). Ingestion of moderate amounts of lactose, however, can be tolerated by most people (Aurand & Woods, 1973). It has been suggested that including lactose in the diet could promote the growth of microorganisms which produce organic acids that inhibit the growth of undesirable bacteria in the large intestine. These organic acids tend to increase the absorption of calcium, phosphorus, and magnesium (Wagner, 1981).

Although its high lactose content limits or excludes the use of whey in certain foods by some European countries (Table 7), the United States, through more advanced whey processing technology, has led the world in whey utilization (Allum, 1980). Allum (1980) reports that, in

Table 7. Permitted use of lactose in certain foods in European countries.

	Denmark			France			Netherlands			UK			Germany		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Application															
Baby food	A									A			A		
Diabetics										A	L		A		
Spec. foods										A			A		
Dairy products		L			L						L	N		L	N
Sweets										A			A		
Cocoa and Chocolate												N	A		
Ice-cream			N							A					N
Bakery goods										A			A		
Bread										A			A		
Flour												N	A		
Noodles										A			A		
Snacks										A			A		
Canned fruits										A					N
Jam, marmalade										A					N
Sweet drinks										A			A		
Fruit juices												N			N
Liqueurs												?			N
Instant drinks										A			A		
Meats					L					A					N
Canned sausage										A					N
Spice and flavorings										A			A		
Mustard										A		N	A		
Dry soups and sauces										A			A		
Mayonaise dips										A				L	

1 = Allowed = A
2 = Limited = L
3 = Not allowed = N

Reprinted from Allum (1980).

the United States during 1977 and 1978, utilization of whey for human consumption exceeded the utilization of whey for animal feed for most processing methods (Table 8).

Extensive research has concerned itself with the use of whey in bakery products (see Cuddy & Zall, 1982 for review). These products provide one of the most important outlets for whey and whey products (Mann, 1982), in part because whey has been described as being one of the least expensive potential ingredients in a baker's formulation (Hugunin, 1980). Vetter (1980) reports that, in 1979, about 9% of the total dried whey in the United States was used in bakery foods. Current research (Zadow & Abhayaratna, 1979; Vetter, 1980; Potavina et al., 1982; Puchkova et al., 1982; Sanchez et al., 1982) suggests that the proportion of variety breads has increased substantially since 1972, and that whey could be used in these breads to enhance their flavor and textural characteristics. Although its incorporation results in a reduction of loaf volume (Zadow & Abayaratna, 1979), by controlling the amounts of whey added to the mixture, it has been found that an acceptable volume with flavor can be obtained (Sanchez et al., 1982; Cuddy & Zall, 1982). Some additional advantages of using whey in bread products are a lighter volume, and a very high resistance to molding (Potavina et al., 1982).

Other common bakery products using whey include muffins, rolls, pastas, cookies, crackers, pie crusts, and fillings (Wagner, 1981; Mann, 1982; Cuddy & Zall, 1982; Puchkova et al., 1982). Research in these areas has shown similar positive findings to the research on utilization of whey in bread production.

Table 8. Production of processed whey products (in thousands of pounds) USA.[a]

Product	1977[b]	1978
Condensed whey solids content		
Sweet-type		
Human food	115,353	118,207
Animal feed	17,278	25,724
Acid-type		
Human/animal feed	12,862	10,811
Total	145,493	154,742
Dry whey		
Human food	472,512	534,741
Animal feed	152,737	173,670
Total	625,249	708,411
Modified dry whey products		
Partially Delactosed		
Human food	26,845	32,280
Animal feed	117,058	130,196
Total	143,903	162,476
Partially demineralized		
Human food	27,604	28,677
Animal feed	c	c
Total	27,604	28,677
Partially delactosed/demineralized		
Human food	7,475	8,909
Animal feed	d	d
Total	7,475	8,909

Table 8. Continued.

Product	1977[b]	1978
Lactose		
Human food	102,841	108,886
Animal feed	5,974	5,299
Total	108,815	114,185
Whey Solids in Wet Blends		
Human food	23,867	34,409
Animal feed	44,438	60,851
Total	68,305	95,260
GRAND TOTAL	1,126,844	1,272,660

[a] Reprinted from Allum (1980).

[b] Revised.

[c] None reported.

[d] Not published to avoid disclosure of individual plant operations.

Another leading use of whey is in dairy product formulations. It has been noted that there is an increasing application of whey especially in the production of ice cream and frozed deserts (Schmidt & Morris, 1984; Stull et al, 1977; Trzecieski, 1982; DeMott & Sanders, 1980; Young et al, 1980). Usually cottage cheese whey solids are processed to demineralize acid whey by electrodialysis (Williams, 1980), although in some applications, fresh fluid acid whey has been used (Young et al, 1980). Studies have shown that up to 25% of the dried skim milk commonly used in ice cream can be replaced by whey products without significant loss in ice cream quality, however, the whey taste influenced the quality of the ice cream at substitution levels higher than 25% (Mann, 1982). For frozen desserts, Stull et al (1977) found that there was no difference in preference for quiescently frozen novelties formulated with water or ones containing untreated cottage cheese whey. With the inclusion of succinylated whey in ice cream, Thompson et al (1983) noted that there was an increased viscosity and melting resistance, and a reduction of freezing time and overrun. In addition, they reported that flavor acceptability of the ice cream decreased with increased substitution (above 10%).

Other common dairy products using whey include cheese, cheese spreads, whey butter, cream sauces, and yogurt (Egnell, 1982; Veinoglou et al, 1982; Iwasawa et al, 1982; DeMott et al, 1980). Research in these areas has shown that whey can serve as an acceptable substitution for dried skim milk, however, caution must be taken in terms of the percentage of substitution depending on the product.

Of growing interest is the inclusion of whey in other types of foods. Whey is added to such preparations as infant foods, salad dressings, instant pudding, cured meat products and meat preserves, and snack foods (Jelen, 1983; Mann, 1982; Mickle et al., 1980; Thompson et al., 1983; Wagner, 1981). Because of its contributions, such as its high quality protein, enhancement of flavors in certain foods, ability to provide desirable acidity or sweetness to certain foods, ease of blending, and low costs, whey has become an attractive ingredient in these preparations.

Whey Utilization in Beverages

Extensive literature suggests that whey could be used in the formulation of nutritious soft drinks, high-protein beverages, and fruit juices (Keay, 1971; Holsinger, 1972; Holsinger et al., 1974). Most research on the manufacture of whey-based soft drink beverages has used sweet whey concentrates or powders, however, the research concerned with fruit juices or citrus drinks has included acid whey (Nelson & Brown, 1969, 1971; Guy et al., 1968; Kosikowski, 1968). In high-protein beverages, either fluid acid or sweet whey is used (Holsinger, 1974). In comparison to other types, the citrus flavored beverages, especially orange, have the highest overall acceptability (Holsinger, 1972). In addition, Holsinger (1972) reports that the protein content is lowest for snack-type beverages, and only the liquid breakfast formulations have protein contents similar to milk (Table 9).

Holsinger et al. (1974) have suggested that whey beverages can be classified into four major groups: (1) high protein beverages in the form of milk-like beverages and beverages resembling soft drinks; (2) non-alcoholic beverages from deproteinized whey; (3) alcoholic beverages

Table 9. Recent research toward production of nutritious whey beverages.

Beverage Use	Formulation			Protein (%)
Snack-type beverages	Acid whey powder or Fluid acid or Sweet whey	+	Fruit juice or Fruit juice concentrate (orange)	0.5-1.0
Imitation milk	Fluid acid or Sweet whey	+	Vegetable hydrocolloids + Vegetable oils	1.0-1.5
Liquid breakfast	Fluid acid or Sweet whey		Soybean powder + Citrus flavoring	2.5-3.5

containing protein, and (4) beverages from whole whey. This guide is useful for describing whey utilization in beverages.

1. Most of the research on high-protein beverages has focused on snack-type beverages, milk-like beverages, and liquid breakfasts. The snack-type beverages resemble soft drinks. Their protein content is low and usually ranges from 0.5% to 1.0%. Typically, these whey-based drinks are flavored with fruit juices or concentrates (Holsinger, 1972). The formulation consists of acid whey powder, fluid acid whey or sweet whey added to the fruit juice or concentrates. For example, Nelson and Brown (1969) formulated a whey-based citrus drink consisting of 25% to 40% fluid whey combined with 7% to 20% citrus juice (e.g., grapefruit, orange, strawberry).

In liquid breakfast formulations, usually a cereal protein such as soybean is added. For example, Guy et al. (1968) combined soy flour with either sweet or cottage cheese whey, then added sugar or artificial sweetner, citric acid, stabilizer, and flavoring to produce an acceptable tasting, low cost, citrus flavored beverage. Results of their experiment showed that the beverage had a pH of 4.4 and 16.5% solids. It contained 2.7% protein and was rated 6.0-6.5 on a 9-point hedonic scale.

In milk-like beverage formulations, vegetable hydrocolloids and oils are suspended or emulsified in whey. For example, Brunner et al. (1969) developed a milk-like beverage called "Way-Mil". This beverage was formulated from whey, selected vegetable oils, vegetable hydrocolloids and, in some applications, skim milk. The beverage contained 1% to 1.5% protein. Similarily, Edmondson et al. (1968) produced a milk-like beverage using sweet whey and cream. Results of this experiment showed that, when compared to commercial chocolate drinks with a hedonic rating of 6.9 on a 9-point scale, the product scored 6.5.

In other studies that described the use of whey as a milk substitute, beverages were produced with such flavors as strawberry, lemon, chocolate, and peanuts (Vajdi & Pereirea, 1973; Wagner, 1981). These formulations resulted in beverages with protein contents ranging from 0.5% to 3.7% and overall acceptabilities were rated from 6.0 to 6.7 on a 9-point hedonic scale. Some beverages were compared to commercial drinks and no significant differences were found between the comparisons.

2. Nonalcoholic beverages can be made from deproteinized whey by removal of the protein either before or after fermentation. The most popular method for deproteinization is by heating acidified whey to about $90^{\circ}C$ and removing the protein by filtration or centrifugation (Holsinger et al., 1974). The deproteinized whey can then be used as a base for unfermented and carbonated nonalcoholic beverages.

Usually unfermented, nonalcoholic beverages are produced by the addition of leaf extracts or by natural vegetables or fruit juices. An example of this type of beverage is "Detskii" that is made with deproteinized whey, carrot juice, and sugar, and contains less than 20% total solids (Holsinger et al., 1974). In addition, nonalcoholic beverages can be carbonated, if desired, and, in this application, the beverages are similar to soft drinks.

Kuzmina (1966) described two sparkling beverages. One contained tomatoe juice, citric acid, and salts; the other was flavored with orange and lemmon. The acidity obtained in both beverages was very high (as cited in Holsinger, 1974). In Russia, a carbonated whey beverage was produced by filtering the whey, followed by centrifugation and carbonation (Mann, 1983). Also, a patent issued to Murray (1968) described a process in which whey was deproteinized with citric and tannic acids; then the whay was filtered, flavored, and bottled.

The carbonated nonalcoholic beverages follow similar processes to that of unfermented beverages, except that the carbonated beverages are incubated with yeasts or other microorganisms and sucrose to develop carbonation. For example, a commly used drink called "Rivella" was introduced as a theraputic tonic in Switzerland in 1952. This beverage was prepared using lactic acid bacteria to ferment the deproteinized whey. The product was then filtrated and concentrated. Swiss alpine herbs and sugar were added for flavoring. The final steps of the process involved a second filtration, dilution, and carboantion of the product. The beverage produced was a crystal clear infusion of herbs, and it has met with wide acceptance throughout most European countries (Holsinger, 1972, 1978; Holsinger et al, 1974; Wagner, 1981).

In Poland, two successful beverages have been produced: a whey champagne (Lactovit) and whey Kwas. In fact, the sparkling whey champagne had an annual consumption of about 230,000 liters (Mathur & Shahani, 1979). Whey champagne is a nonalcoholic beverage prepared with deproteinized whey and sugar to which yeast is added. After incubation, the beverage is colored with caramel, flavored, and bottled (Holsinger, 1972, 1974).

Whey Kwas was prepared from fresh sweet whey. Its preparation involved the separation and deproteinization of the whey, followed by inoculation with a thermophilic starter. After a 2 hour incubation period, yeast and caramel color were added, and the product was bottled and held at $8^{o}C$ for 40 hours.

In Czechoslovakia, a flavored whey beverage was made by mixing whey, sugar, and a stabilizer. The beverage was pasteurized at $80^{o}C$, homogenized, and inoculated with a Lactobacillus starter. After incubation, sugar and fruit concentrates were added. Subsequently, the beverage was repasteurized and rehomogenized (Mann, 1983). Other studies that described the use of whey in acceptable carbonated nonalcoholic beverages have been reported (Hagiwara et al., 1981; Mann, 1983; Holsinger et al., 1974).

3. Whey alcoholic beverages differ extensively in alcohol content depending on the type of beverage desired. For example, "Whevit", a sparkling beverage produced in India, has 0.5% to 0.7% alcohol (Holsinger, 1974), and a whey wine produced in the United States has an alcoholic content of 10% (Yoo & Mattick, 1969). For wine, usually the procedure consists of fermenting whey and sucrocse with yeast or other microorganisms, and the mixture ages approximately 3 months, although, at times, only the lactose in the whey is used rather than adding sucrose. In addition, lactose in acid whey usually ferments more rapidly and produces more alcohol than sweet whey (Yoo & Mattick, 1969). For example, Yoo and Mattick (1969) developed a wine from both sweet and acid whey. They found that ethyl alcohol production from whey was maximum with a 12% lactose concentration. They reported that an acceptable wine was produced

containing 10% alcohol with 16% added sucrose and a 10% acid whey solution.

Another example of an alcoholic beverage using whey can be found in the production of whey beer. Deitrich (as reported by Holsinger et al., 1974) produced a beer substitute by formulating 5.4% malt wort with 2.5% deprotenizied whey. After 5 to 7 days fermentation, it was found that the product had developed a true beer flavor and character. Because whey has the ability to bind carbonic acid, its inclusion in beer is feasible (Holsinger et al., 1974).

Other beers and wines have been produced (Table 10) and have met with great acceptance (see Holsinger et al., 1974 for review). In addition, the inclusion of whey in other types of alcoholic beverages include whey champagne (Lactovit) and whey Kwas (Holsinger, 1972, 1978). A brief summary of these types of beverages is shown (Table 10).

4. Whole whey beverages require no processing except pasteurization. Depending on the end properties or characteristics desired, the whey can be deodorized and/or neutralized. Subsequent flavoring and packaging are all that is necessary. Whole whey has been used in the formulation of juices and soups. For example, Nelson and Brown (1971) produced beverages consisting of 31% whole whey combined with a mixed variety of citric flavorings, natural juices, and purees. Interestingly, the comparison between a nonwhey drink and a whole whey drink showed that the whole whey drink was rated 6.3 on a 7-point hedonic scale and the nonwhey drink was only rated at 4.7 by 51 tasters. They also added that the whey contributed to the color and flavor stability.

Table 10. Commercially produced carbonated beverages from whey.

Brand	Year Marketed	Country of Origin	Type
Rivella	1952	Switzerland	Nonalcoholic Herbs
Whey Champagne	1966	Poland	Alcoholic, wine-like
Whey kwas	1966	Poland	Alcoholic, Kefir-like
Bodrost	1969	Russia	Alcoholic, beer-like
Tai	1971	Brazil	Nonalcoholic, citrus

Orange-flavored and lemon-lime flavored beverages were formulated by DeMott (1975) with direct acidification cottage cheese whey. This beverage was rated acceptable, and the orange-flavored beverage was preferred over the lemon-lime flavored beverage.

Holsinger et al. (1974) suggest that using whole whey is the least expensive, most efficient method. Perhaps this economically feasible process makes this method attractive to manufacturers, and they might produce more beverages in an effort to utilize more of the liquid whey.

Puffed Rice

Puffed Rice Production

Following the concept provided by popcorn, there have been efforts to puff other whole kernels. One such kernel is rice. To puff, the rice is prepared by cleaning, conditioning, and depericarping (by a wet scouring process). A batch of the prepared grain is fed into a pressure chamber, which is then sealed, and heated externally by injection of steam so that the internal pressure rapidly builds up to about 13.95 kg/cm^2. The pressure is then suddenly released by opening the chamber. This method has been referred to as a "puffing gun". Expansion of water vapor or the release of the pressure blows up the grains to several times their original sizes. The puffed product is dried to 3% m.c. by toasting, cooled and packaged (procedure reported by Kent, 1975). Desirable rice for puffing should have a thin, weak aleurone layer and a large clearance between husk and kernel for easy shelling.

Another method consists of partially cooking the rice (parboiling) and pearling the rice. Subsequently, sugar and salt are added to the mixture, then the rice is cooked, and the resultant lumps are broken and dried. The partially dried rice is then stored to allow the moisture to distribute uniformly in the grain mass. This process is referred to as a "tempering process". After about 15 hours, lumps begin to form with the rice and they must be broken up before being sent to flaking rolls. After re-drying to a moisture content of 18% to 20%, the rice grains are passed under a radiant heater, bringing the external layer of the rice to 82.2^{o}C. This method inhibits the outside layers of the kernels from splitting when the grain is then run through the flaking rolls. When the rice is passed through the flaking rolls, only the central part of the rice kernel is contacted. The kernels are re-tempered and passed through toasting ovens at 232.22^{o}C to 301.66^{o}C for about 30 to 45 seconds (procedure reported by Matz, 1970).

The protein content of puffed rice resembles the protein content of the original rice (approximately 6.3%) and is a fairly well-balanced amino acid array. The composition of puffed rice is shown (Table 11).

To date, puffed rice has had limited uses. The most common use is in breakfast cereals (Matz, 1970). It can be used without further processing or included in other types of cereals. For example, a cereal called "Special K", manufactured by the Kellogg Company, is a rice kernel with other additives such as wheat gluten, wheat germ meal, dried skim milk, and other nutritional adjuncts (Matz, 1970). Also, Martin (1977) reported that puffed rice was incorporated in a granola-type cereal.

Puffed rice has also been used in certain confections. For example, Riedel (1983) describes the use of puffed rice in chocolate and granola bars.

Table 11. Composition of puffed rice.

Nutrients	Amount in 100g, edible portion	Amount in edible portion of common measures of food ½ oz = 14.2g	1 c = 14g	Amount in edible portion of 1 pound of food as purchased
	GRAMS			
Proximate				
Water	3.0	0.4	0.4	13.6
Protein	6.3	0.9	0.9	28.7
Total lipid	0.5	0.1	0.1	2.1
Carbohydrates	89.8	12.8	12.6	407.3
Crude fiber	0.4	0.0	0.0	1.6
Dietary fiber	0.5	0.1	0.1	2.2
Ash	0.4	0.1	0.1	2.0
Amino acids				
Tryptophan	0.094	0.013	0.013	0.426
Threonine	0.318	0.045	0.045	1.442
Isoleucine	0.336	0.048	0.047	1.524
Leucine	0.526	0.075	0.074	2.386
Lysine	0.268	0.038	0.038	1.216
Methionine	0.189	0.027	0.026	0.857
Cystine	0.108	0.015	0.015	0.490
Phenylalanine	0.270	0.038	0.038	1.225
Tyrosine	0.355	0.050	0.050	1.610
Valine	0.411	0.058	0.058	1.864
Arginine	0.519	0.074	0.073	2.354
Histidine	0.191	0.027	0.027	0.866
Alanine	0.261	0.037	0.037	1.184
Aspartic acid	0.583	0.083	0.082	2.644
Glutamic acid	1.015	0.144	0.142	4.604
Glycine	0.366	0.052	0.051	1.660
Proline	0.266	0.038	0.037	1.207
Serine	0.287	0.041	0.040	1.302

CHAPTER 3

MATERIALS AND METHODS

Starting Materials

Acid Whey

Fresh, fluid acid whey containing slightly more than the normal amount of cheese curd particles was supplied by a local commercial food processing plant (Shamrock Foods Company, Phoenix, Arizona) and shipped frozen in 22.8 liter plastic containers. Whey was about 2 to 3 days old before processing began. No treatment was given to the whey prior to beverage formulation and processing.

Puffed Rice

Malt-O-Meal puffed rice without sugar, salt, or preservatives was used in the beverage formulations. The puffed rice was milled through a .024 mesh (Weber Brothers and White Metal Works, Inc., model 22) to obtain a fine flour prior to its use in beverage formulation and processing. The puffed rice was obtained from a local food store.

Diacetyl

Hansen's starter distillate was used in four of the eight mix formulations.

Other Ingredients Used

Vanilla - Tone's imitation vanilla flavor (8-Fold).

Sugar - Kingston granulated sugar.

Dry Skim Milk - Carnation Non-Fat Dry Milk, fortified with vitamin A and D without preservatives.

Cinnamon - Tone's ground Karintji cinnamon.

Emulsifier - Myvatex food emulsifier (Type 8-20E).

Hydrodenated Soy Bean Oil - Mello Mix, Humko Products.

Composition

The composition of the whey and rice was determined as follows:

Acid Whey

Total Solids (TS). Total solids were determined in a Mojonnier Milk Tester. A 2 gram sample was spread in a thin film over the bottom of a tared aluminum dish. The dish was placed on the Mojonnier's exterior hot plate and heated at 180°C until the first traces of brown color began to appear in the residue. The sample was placed in an oven at 100°C for 10 minutes under not less than 508 mm of vacuum. The sample was cooled in a desiccator with continuous water circulation. After 5 minutes, the residue was quickly weighed to determine the percent total solids. This procedure was performed in triplicate.

Lactose. Lactose was determined by the Teles et al. method (1978). A 2 ml sample of whey was placed in a 100 ml volumetric flask and diluted to volume with distilled water. Then, 0.2 ml 5% zinc sulfate and 0.2 ml

4.5% barium hydroxide were added to a 2.5 ml aliquot of the diluted whey sample in a centrifuge tube. The samples were centrifuged for 1 minute at 1000 rpm. One mililiter of the clear supernatant was transferred to a Folin blood tube and 2.5 ml of Teles' reagent were added. The tubes were sealed tightly with rubber stoppers and immersed in a bath of boiling water for 6 minutes. After cooling with tap-water, distilled water was added to dilute the samples to 12.5 ml and the samples mixed thoroughly. A spectophotometer (Baush and Lomb Spectronic 20) was used to read the absorbance at 520 nm against a similarly treated reagent blank. Lactose percentage was calculated using a standard curve.

Acidity. Acidity was determined by the AOAC method (1975). A 20 ml sample was neutralized to a pH of 6.8 and was placed in a suitable dish. The sample was diluted with 40 ml CO^2- free water. Two mililiters of phenolphthalein were added, and the sample was titrated with 0.1 normal sodium hydroxide until a persistent pink color was obtained. Acidity was expressed as percent lactic acid.

Fat. The AOAC method (1975) was followed to determine fat content. Ten grams of sample were transferred to a fat-extraction flask, and 2 ml of ammonium hydroxide were added. This addition was mixed thoroughly. Ten mililiters of alcohol were added to this solution and mixed well. Then, 25 ml of ethyl ether were added, and rubber stoppers were used to seal the flask tightly. Then, the mixture was shaken vigorously for 1 minute. Then, 25 ml of petroleum ether was added and mixed thoroughly. The samples were centrifuged in a Mojonnier tester for 30 seconds, and the clear supernatant was decanted into a tared aluminum dish. The lid and stopper of the extraction flask were washed with a mixture of equal parts of petroleum ether and ethyl ether and were added to the weighing dish. The extraction of the liquid remaining in the flask was repeated using 15 ml of each solvent. The solvents were evaporated completely by a steam bath, and the dishes were dried to constant weight in a vacuum oven at 75°C under pressure not less than 508 mm vacuum. The dishes were cooled to room temperature and quickly weighed. The fat was removed completely from the dish with 25 ml of petroleum ether, and the dishes were dried and weighed again.

Protein. The AOAC micro-Kjeldahl method (1975) was used to determine protein. A 150 mg sample was placed into a Kjeldahl flask and approximately 0.2 g of catalyst were added. A 10 ml mixture of sulfuric and phosphoric acids were added. A boiling stone was included to reduce frothing. The flask was placed on a digester under a hood at low temperature. After 30 minutes, a higher temperature was used until the sample was digested. The sample was tranferred to a 25 ml volumetric flask and distilled water was added to volume. A 2 ml sample aliquot was placed in a distillation apparatus and 10 ml 40% sodium hydroxide was added. A flask containing 10 ml 2% boric acid solution and 3 drops of indicator solution was attached to the apparatus and the condenser tip was immersed in these solutions. After the first drop of condensate fell from the cold finger into the boric acid solution, the apparatus was timed to operate for an additional 2½ minutes. Then the flask with the boric acid solution was lowered until the condenser tip cleared the liquid. The apparatus continued operating in this manner for 30 seconds. The boric acid sample was titrated with 0.01 N HCL until there was a distinct color change.

Amino Acids. Duplicate 150 mg samples were placed into a 250 ml round bottom flask, and 100 mg sodium thioglycollate was added to one of the duplicates. To each flask, 25 ml of 6N HCL acid were added and then they were covered by an inverted small beaker. The samples were heated under 508 mm pressure at 121^{o}C for 16 hours. The samples were evaporated to dryness under vacuum, rinsed with distilled water and dried 3 times. They were then disolved with 1 ml of sodium citrate buffer (pH=2.2) for each estimated percentage of protein in the sample. Each sample was filtrated into a vial through a Whatman #1 paper until the sample was clear. The pH of the samples was adjusted to 2.2, and they were refrigerated overnight before analysis by ion-exchange chromatography.

pH. A Fisher Accumet, (Model 220) instrument with a combination electrode was used to measure pH.

Ash. The AOAC method (1975) was used to determine ash content. A 5 g well-mixed sample was placed into a previously dried (100^{o}C), cooled, and weighed ashing dish. The sample was transferred to a furnace and ignited to 550°C to constant weight. The sample was cooled in a desiccator and weighed immediately after it reached room temperature.

Puffed Rice

Total Solids (TS). Total solids were determined by the AOAC method (1975). A 2 g well-mixed sample was placed in a covered dish previously dried at 100°C, cooled in a desiccator, and weighed immediately after reaching room temperature. The sample was heated in a vacuum oven at 100°C to constant weight under pressure of not less than 508 mm vacuum. The sample was transferred to a desiccator until it reached room temperature, and the residue was immediately weighed for percent total solids.

Ether Extract. The AOAC method (1975) was followed to determine ether extract. Two grams of ground well-mixed sample were placed in a Mojonnier fat-extraction tube, and 2 ml alcohol were added to reduce lumping with the addition of acid. Particles were moistened by shaking. Ten ml 8N HCL was added, mixed well, and transferred to a hot water bath (75°C) for 30 minutes. The sample was cooled to room temperature, and alcohol was added until the liquid level rose to the constricted portion of the Mojonnier flask. To this sample, 25 ml ether were added; covered with a thoroughly cleaned rubber stopper; and shaken vigorously for 1 minute with frequent release of pressure. Solvent and fat were washed from the stopper with 25 ml petroleum ether. The samples were stoppered and shaken vigorously for one minute. The sample was centrifuged in the Mojonnier for 30 seconds. The ether fat solvent was poured through a funnel packed with cotton into a 150 ml beaker. Extraction was repeated twice; each time with 15 ml of each ether and shaken for 1 minute after the addition of each ether. The clear ether solution was poured through a filter into the same beaker. The solution was evaporated slowly on a steam bath, and heating continued for 15 minutes after the solution had evaporated; then it was cooled to room temperature. After cooling, the dried fat residue was redissolved in four 10 ml portions of ethyl ether, each filtered through cotton into a 100 ml beaker. The ether was evaporated on a steam bath, and the sample was dried at 100^{0}C for 90 minutes, cooled to room temperature in a desiccator, and weighed immediately.

Protein. The AOAC micro-Kjeldahl method (1975) was used to determine protein. This determination followed the same procedure as that for protein in acid whey.

Amino Acids. These constituents were determined by the same procedure followed for the determination for amino acids in acid whey.

Ash. The AOAC method (1975) was used to determine ash content. The determination for this constituent followed the same procedure for ash in acid whey.

Acid Detergent Fiber. Two grams of puffed rice flour were placed into a 600 ml beaker. To this material, 100 ml of cold hexadecyltrimethylammonium bromide (2%) dissolved in 1N sulfuric acid were added.

Two mililiters decahydronapthalene were added to facilitate removal of pigments. This solution was heated to boiling (about 10 minutes) and refluxed for 60 minutes from the onset of boiling. The acid detergent fiber was filtered on a dry, tared sintered glass crucible using light suction (tall form, course porosity, 40 mm in diameter), then washed with a stream of hot deionized distilled water (90°C). Adhering particles were washed down from the sides of the crucible, and the fiber was washed twice with about 35 ml of cold acetone. The crucible was aspirated free of acetone and dried in a forced air oven at 100°C for 2 hours. The sample was cooled in a desiccator and weighed immediately.

Preparation of Mixes

Preliminary Formulations

Prior to producing the final beverages, two formulations were produced that simulated a Horchata-type beverage to test the proportions of ingredients and the products' acceptability on a small experimental scale. In the first formulation, whey concentration was held constant, and whole milk, evaporated milk, dry-skim milk (DSM), ground puffed rice, sugar, vanilla, and cinnamon were added. Although the flavor of the beverage was acceptable, whole milk and evaporated milk were excluded for practical reasons. In the second formulation, whey, DSM, ground puffed rice, sugar, vanilla, and cinnamon were blended. In addition, different stabilizers and emulsifiers were varied to test these ingredients. Because most stabilizers gave rather high viscosity similar to a milk-shake beverage, they were eliminated. Myvatex emulsifier (Type 8-20E) was included becasue it gave better consistency. Five persons tested these formulations, and, on the basis of their judgements, the proportions for the final beverages were chosen (Table 12).

Final Formulation Preparations

Beverage formulations were based on a 3 X 2 factorial design. There were three ingredients (whey, rice, and diacetyl) at two levels each (high, low) that produced 8 mix formulations: High Whey Low Rice (HWLR), High Whey Low Rice with Diacetyl (HWLR/D), High Whey High Rice (HWHR), High Whey High Rice with Diacetyl (HWHR/D), Low Whey Low Rice (LWLR), Low Whey Low Rice with Diacetyl (LWLR/D), Low Whey High Rice (LWHR), and Low Whey High Rice with Diacetyl (LWHR/D) (Table 13). All other ingredient concentrations were held constant.

The processing techniques consisted of 11 steps (Figure 1):

Step 1. Puffed rice was ground to a fine flour through a .024 mesh. This size mesh was chosen because the resultant flour is easier to blend, and it is fine enough to prevent clogging during the subsequent homogenization process. After grinding, the flour was placed in large plastic bags and stored in a refrigerator at $9^{o}C$ prior to its use.

Step 2. Six gallons of frozen cottage cheese whey were defrosted in a refrigerator for 2 days to prevent spoiling of and changes in the whey. After defrosting, the whey was neutralized with 6N NaOH to obtain a pH of 6.8. This neutralizer has been shown to be better than

Table 12. Proposed percentages of ingredients for final formulations based on preliminary formulations.

Sample	Whey	Rice	Diacetyl	DSM	Fat	Sugar	Cinnamon	Emulsifier	Vanilla
	%								
A	84.31	5.0	0.0	1.5	2.0	7.0	0.008	0.078	0.12
B	84.31	8.0	0.0	1.5	2.0	7.0	0.008	0.078	0.12
C	81.31	5.0	0.0	1.5	2.0	7.0	0.008	0.078	0.12
D	81.31	8.0	0.0	1.5	2.0	7.0	0.008	0.078	0.12
A'	84.31	5.0	1.0	1.5	2.0	7.0	0.008	0.078	0.12
B'	84.31	8.0	1.0	1.5	2.0	7.0	0.008	0.078	0.12
C'	81.31	5.0	1.0	1.5	2.0	7.0	0.008	0.078	0.12
D'	81.31	8.0	1.0	1.5	2.0	7.0	0.008	0.078	0.12

Table 13. Eight mix formulations produced by 3 X 2 factorial design.

Sample	Ingredient Concentrations Whey	Rice	Diactyl	Formulations
A	High	Low	-0-	High Whey - Low Rice
A'	High	Low	10 ml	High Whey - Low Rice with Diacetyl
B	High	High	-0-	High Whey - High Rice
B'	High	High	10 ml	High Whey - High Rice with Diacetyl
C	Low	Low	-0-	Low Whey - Low Rice
C'	Low	Low	10 ml	Low Whey - Low Rice with Diacetyl
D	Low	High	-0-	Low Whey - High Rice
D'	Low	High	10 ml	Low Whey - High Rice with Diacetyl

1.	Grinding	Grind puffed rice to flour through a .024 mesh.
2.	Neutralizing	Add to whey 6N NaOH to pH 6.8.
3	Weighing	Weigh ingredients for 81% or 84% whey; 7% or 5% puffed rice flour; 1.5% DSM; 7% sugar; and 0.078% emulsifier.
4.	Blending	Add all dry ingredients except cinnamon to whey and blend.
5.	Cooling	Cool and store over night at 9°C.
6.	Mixing	Add 2% fat to formulation.
7.	Heat Treatment	Heat blend to 60°C for 20 minutes.
8.	Homogenizing	Homogenize in a double-stage Manton Gaulin apparatus (model E-200) under 245/35 kg/cm^2 at 95°C.
9.	Cooling	Cool and store over night at 9°C.
10.	Weighing	Weigh ingredients for 0.99% diacetyl; 0.12% vanilla; and 0.008% cinnamon.
11.	Blending	Add diacetyl (to only half of the formulations), vanilla, and cinnamon and blend.

Figure 1. Process for beverage formulation.

other neutralizers for this type of whey (Young et al., 1979; Wagner, 1981). After neutralizing, the whey was mixed by gently shaking the container. The curd particles were allowed to settle, and the whey was transferred to four 18.93 liter pails. Each pail contained 7 kg of well-mixed, neutralized cottage cheese whey.

Step 3. Dry ingredients were weighed to proportions (7% and 5% puffed rice flour; 1.5% DSM; 7% sugar; and 0.078% emulsifier). These proportions were based on the preliminary formulation. The actual percentage of ingredients of the final formulations differed slightly from the proposed percentage (Table 14).

Step 4. The proportions of dry ingredients were transferred to four stainless steel, 3.5 liter beakers; two of which contained a higher percentage of whey (84%) and the other two contained a lower percentage of whey (81%). Each formulation was blended at a low speed to reduce air incorporation and increase in viscosity. Blending continued for approximately 15 minutes or until a smooth texture was obtained.

Step 5. The four mix formulations were refrigerated and held at a low termperature ($9^{o}C$) overnight to allow the particles to rehydrate and to assist in homogenization.

Step 6. The following day, fat was weighed to obtain a 2% proportion and mixed thoroughly. Fat was added to the mixture to improve flavor and texture.

Step 7. The four mix formulations received a heat treatment consisting of placing the containers in a vat of hot water for 20

Table 14. Actual percentage of ingredients for final formulations.

Sample	Whey	Rice	Diacetyl	DSM	Fat	Sugar	Cinnamon	Emulsifier	Vanilla
	%								
A	84.31	4.99	0.00	1.50	2.00	6.99	0.008	0.078	0.12
B	81.86	7.76	0.00	1.45	1.94	6.79	0.007	0.077	0.12
C	83.83	5.15	0.00	1.54	2.06	7.21	0.009	0.080	0.12
D	81.32	7.99	0.00	1.50	2.00	6.99	0.008	0.078	0.12
A'	83.48	4.94	0.99	1.48	1.98	6.92	0.008	0.077	0.12
B'	81.05	7.68	0.99	1.44	1.92	6.72	0.007	0.076	0.12
C'	83.00	5.10	0.99	1.52	2.04	7.14	0.009	0.079	0.12
D'	80.51	7.91	0.99	1.48	1.98	6.92	0.008	0.077	0.12

minutes at 60^{o}C. This procedure was followed to prevent the rapid bacterial growth.

Step 8. To the four mix formulations, 100 ml of distilled water were added to replace the water that evaporated during heat treatment. The formulations were homogenized in a double-stage Manton Gaulin apparatus (Model E-200) at a pressure of 245/35kg/cm^2 at 95^{o}C. The formulations were homogenized to improve texture, viscosity, and appearance.

Step 9. After homogenization, the formulations were cooled in ice to 10^{o}C and stored overnight at 9^{o}C in a refrigerator. Refrigeration was necessary to minimize the evaporation of the subsequent addition of diacetyl and vanilla.

Step 10. Diacetyl, vanilla, and cinnamon were weighed to obtain appropiate proportions (0.99% diacetyl; 0.12% vanilla; and 0.008% cinnamon). These ingredients were added for additional flavoring.

Step 11. The proportions of vanilla and cinnamon were added to and blended with the four mix formulations. Each of the four mix formulations was divided into two containers producing two equal sets of varied proportions of whey and rice. To one set, diacetyl was added and blended, thus, producing eight (8) mix formulations. The 8 mix formulations were stored overnight at 9^{o}C and subsequently subjected to sensory evaluation.

Experimental

Analysis of Eight Mix Formulations

Total Solids (TS). Total solids of the beverages were determined by the AOAC method (1975) as previously described for TS in puffed rice.

Fat. The AOAC method (1975) was used to determine fat content in the beverages. This procedure was previously described for fat in acid whey.

Protein. This constituent was determined by the AOAC method (1975) and previously described for protein and amino acids in acid whey.

Amino Acids. This constituent was determined by the same method for amino acids in acid whey.

pH. A Fisher Accumet (Model 220) instrument with a combination electrode was used to measure pH of the beverage.

Ash. Ash was determined by the AOAC method (1975) and previously described for ash in acid whey.

Sensory Evaluation Methods

Design. A 3 X 2 factorial design with repeated measures was used to evaluate the acceptability of the beverage. Three ingredients (whey, rice, and diacetyl) each at two levels (high, low) produced 8 mix formulations. Low concentration of diacetyl represented no addition of diacetyl.

Test Panel and Procedures. Acceptability of the beverages was evaluated by a 52 member untrained panel consisting of 37 females and 15 males (ages 18-51 years) from University faculty, staff, and students. Participation as a member and completion of information found on the scoring sheet regarding age, ethnicity, and sex were voluntary. Each panelist was randomly assigned to one of eight testing booths located in an adequately lit and comfortable cooled laboratory. To accommodate the availability of space, testing sessions were from 8:00 a.m. to 12:00 p.m. on each of two successive days. The panelists were told that they were going to evaluate different attributes of beverages. They were also told that their first impression was most important; to taste each beverage and immediately evaluate it; and that it was only necessary to sip each beverage. Water was made available for optional mouth rinsing between samples.

Scoring Sheet. Each panelist was given 8 scoring sheets (Figure 2). Each scoring sheet contained 5 sensory attributes (appearance, viscosity, texture, flavor, and overall acceptability) each with an adjacent 9-point hedonic rating scale ranging from 9 - "like-extremely" to 1 - "dislike extremely". This scale has been used successfully in sensory evaluations of other types of beverage products (Young et al., 1979; Wagner, 1981). Panelists were given instructions on how to complete the scoring sheet and a #2 pencil for their convenience.

Presentation of Samples. Each panelist received 15 g of 8 samples that were contained in a 28 g paper cup. Each cup was coded

BEVERAGE TASTE TEST

JUDGE NO. ________ TEST NO. ______

Please circle the correct information or fill in: TEST DATE ______

AGE RANGE: 18-25 26-30 31-40 51 and over
SEX: Male Female
ETHNIC GROUP: ______________

SAMPLE ________

You are being asked to evaluate 8 beverage samples. Evaluate the beverage on each attribute. Overall acceptability should indicate your total evaluation of the beverage. Greatest accuracy and reproductibility can be expected if you base your evaluation on one taste of each sample. You may rinse your mouth with water (if you like) from time to time. Draw a vertical slash across the horizontal line at the point which reflects your judgement of the sample. If you have any questions, please ask the research technician.

	Dislike Extremely				Neither Like Nor Dislike			Like Extremely	
	1	2	3	4	5	6	7	8	9
Appearance									
Viscosity									
Texture									
Flavor									
Overall Acceptability									

Comments:

Figure 2. Sample score sheet used by panelists in the rating of beverages during sensory evaluation.

with nonsense symbols (Table 15) according to the beverage formulation. Samples were randomly presented according to a Youden Square (Winer, 1962) to minimize order effects. No practice samples were given to the panelists. Beverages were mixed 20 hours before presentation and refrigerated over night at about 9°C. During presentations, the beverages were kept cool by refrigeration.

Table 15. Codings used for beverage samples during sensory evaluation.

Sample	Code	Formulation	
A	:	High Whey - Low Rice	HWLR
B	⊦	High Whey - High Rice	HWHR
C	)	Low Whey - Low Rice	LWLR
D	∧	Low Whey - High Rice	LWHR
A'	□	High Whey - Low Rice with Diacetyl	HWLR/D
B'	#	High Whey - High Rice with Diacetyl	HWHR/D
C'	∸	Low Whey - Low Rice with Diacetyl	LWLR/D
D'	⊓	Low Whey - High Rice with Diacetyl	LWHR/D

CHAPTER 4

RESULTS AND DISCUSSION

Whey

The composition of the whey was generally within the expected values (Table 16). Total solids of the acid whey were slightly below the literature reports (U.S. Department of Agriculture, 1976). This may be due to normal variations usually found in fluid acid whey and its products composition, and, in part, due to the addition of the whey neutralizing solution. The ash content was slightly higher. The addition of potassium hydroxide during neutralization could account for some of this increase. The determination of lactic acid was calculated for neutralized whey and non-neutralized whey. For neutralized whey (pH = 6.8), the lactic acid was considerably lower (0.13%), and for non-neutralized whey (pH = 4.8), the lactic acid content was slightly higher (0.52%) than the expected value.

Puffed Rice

The composition of puffed rice was within expected values (Table 17). Total solids were slightly lower than those reported in the literature (U.S. Department of Agriculture, 1976). This may be due to the absorption of humidity in storage environments. The puffed rice was stored in a refrigerator for approximately one month prior to analysis. The storage conditions from manufacture to purchase was not ascertained. Determination

Table 16. Composition of acid whey compared to expected values[a].

Component	Acid whey (Curd particles included)	
	Determined	Expected
	%	
Moisture	93.79	93.42
Lactose	3.87	4.90[b]
Total Protein	0.78	0.76
Fat	0.08	0.09
Ash	0.93	0.61
Lactic Acid	0.52	0.40[b]
Total Solids	6.21	6.58

[a] Values reported by the Food and Agriculture Organization (1974).

[b] Values reported by Wagner (1981).

Table 17. Composition of puffed rice compared to expected values.

Component	Puffed Rice Determined	Puffed Rice Expected[a]
	%	%
Moisture	7.08	3.00
Ether Extract	1.79	0.50
Protein	5.29	6.30
Ash	0.30	0.40
Acid Detergent Fiber	0.50	0.40
Carbohydrates (by difference)	85.04	89.80
Total Solids	92.92	97.00

[a] As reported by the Food and Agriculture Organization (1974).

of ether extract showed a considerably higher fat content (1.79%) as compared to the expected value (0.50%). This difference may be attributable to increases in fat content produced by processing. Protein content was considerably lower than the expected value, which, in part, may be due to the combination of the type of rice used to produce the puffed rice and the manufacturing process.

Beverages

The composition of the beverages was within expected values (Table 18). Overall, the beverages showed slightly higher total solids content than the expected values, and, this difference is attributable to several possible explanations. First, during refrigeration, some of the water in the beverages may have evaporated. Second, some of the total solids in whey could be curd particles, since the whey contained slightly higher normal amounts of this material and the whey was allowed to sediment for a longer period of time. Thus, the final batches of whey used for beverage formulations could have contained higher total solids content than earlier batches. Third, during storage, some of the diacetyl could have evaporated which could also account for the variations found among the beverages containing diacetyl. Fourth, there were variations found among all formulations. For example, the formulations containing low whey and high rice concentrations were compared to the formulations containing high whey and low rice concentrations. The determined values for the low whey and high rice concentrations were lower than the expected values, but the determined values for high whey and low rice concentrations were higher.

Table 18. Composition of beverages as compared to expected values.

Beverage		Moisture		Fat		Protein		Ash		Total Solids	
		%									
		D[a]	C[b]	D	C	D	C	D	C	D	C
A	HWLR	78.87	79.09	1.66	2.12	1.32	1.48	0.94	0.66	21.13	20.91
B	HWHR	76.81	76.87	1.63	2.06	1.46	1.62	0.87	0.65	23.19	23.13
C	LWLR	78.45	78.65	1.64	2.15	1.64	1.50	0.91	0.66	21.55	21.35
D	LWHR	76.43	76.39	1.76	2.09	1.83	1.65	0.88	0.65	23.57	23.61
A'	HWLR/D	78.90	79.31	1.58	2.07	1.23	1.46	0.93	0.65	21.10	20.69
B'	HWHR/D	77.02	77.12	1.77	2.02	1.39	1.86	0.90	0.64	22.98	22.88
C'	LWLR/D	78.69	78.86	1.67	2.13	1.45	1.76	0.89	0.65	21.31	21.14
D'	LWHR/D	76.45	76.63	1.66	2.07	1.67	1.90	0.94	0.65	23.55	23.37

[a] Determined values.

[b] Calculated values.

Thus, the whey seems to have contributed more to the total solids content. It is important to note that, although variation was found among the beverages, the standard deviation was small (SD = 1.12).

Overall, the fat content was below the calculated values for all the beverages. However, the formulations with diacetyl showed less difference between the determined values and the expected values than those formulations without diacetyl. The overall reduction in determined values may be due to fluctuations in oven temperatures during analyses (70°C to 120°C), and this inconsistency in temperature may have altered the fat composition. The fat content of the beverages that contained diacetyl more closely resembled the expected values primarily because the beverages were stored for 4 days prior to the determination, and some of the diacetyl could have evaporated during this period. Thus, the percentages of other ingredients contributing to the fat content would have increased by difference.

The ash content was higher than the expected values, but this was probably due to the higher ash content primarily in the neutralized whey. Similarly, the protein contents of the beverages were low overall, and this was probably due to the lower protein content found in the original whey and puffed rice. Although these determined values were lower, with the exception of the C- and D-formulations, the protein contents were within the expected range.

The D-formulation of low whey and high rice concentration had the highest protein content and the least amount of ash of all the beverages.

In addition, this beverage showed the least difference between the determined value and the expected value for total solids content.

Amino Acid Content

Comparison of the essential amino acid pattern of the beverages to the FAO recommended pattern was made (Table 19). All formulations showed a higher amino acid pattern than the FAO pattern, and, as evidenced by chemical analysis, the formulations produced beverages of high nutritional quality. Beverages B and B' (HWHR and HWHR/D) had the highest overall essential amino acid content.

pH

The initial pH of the cottage cheese whey was 4.6. The whey was neutralized with 6N KOH to pH = 6.8 prior to beverage formulation and processing. Beverage pH values ranged from 6.70 to 6.77 (Table 20), and were within the expected values.

Stability

Stability of the beverages varied according to the formulations. A sample of each batch was placed in graduated cylinders and stored at 9^{o} C for 14 days to observe separation and the rate of settling. Formulations D and D' (LWHR and LWHR/D), with the highest amount of total solids, showed the highest stability, even after five days of observation. The formulations A and A' (HWLR and HWLR/D), with the lowest total solids content, separated after one day, and showed the highest rate of settling and the highest instability. Since no stabilizers were used in the formulations,

Table 19. Essential amino acid content of whey, rice, and beverages as compared to the Food and Agriculture Organization (FAO) recommended pattern.

Amino Acid	Whey	Rice	Beverages A	B	C	D	A'	B'	C'	D'	FAO[a]
	g/100g protein										
Lysine	8.61	3,11	7.22	8,73	6.79	5,21	7,57	8,30	7,48	6,94	4,20
Leucine	10.67	10.94	10.68	12,71	8,50	9,00	9,31	11,19	9.95	10,86	4.80
Threonine	4.45	3,53	4,06	4,86	3,74	3,10	4,91	4,97	4,15	4,05	2,80
Valine	5.20	6.52	5,91	7.38	5.42	4,49	7,05	7.25	5,96	6,02	4.20
Methionine	2.38	3.64	2,90	3.58	2.30	2,46	2,92	3.07	3.03	2,99	2.20
Isoleucine	5.09	4,83	5,09	6.16	4.52	3.91	5,64	5,88	5.12	5,07	4.20
Phenylalanine	3.63	5,68	4.42	5,65	4.12	3.48	5,40	5.74	4.61	4,62	2.80

[a] Food and Agriculture Organization (1976).

Table 20. Determined pH for beverages neutralized with 6N KOH.

Beverage	pH
A	6.77
B	6.72
C	6.75
D	6.73
A'	6.72
B'	6.70
C'	6.75
D'	6.73

the beverages with the higher total solids appeared to contribute to stability because they precipitated at the slowest rate.

Beverage Description

The beverages were creamy, light brown in color. The intensity of brown increased with higher concentrations of rice. Thus, this attribute seemed to be strongly influenced by the color of the rice. The odor was predominately a combination of vanilla and cinnamon, except in the beverages that contained diacetyl. For those beverages, the diacetyl odor dominated the other flavorings.

Sensory Evaluation

The scores from the hedonic ratings were subjected to two statistical analyses: an overall analysis, in which the formulations and the flavoring (diacetyl) addition were examined, and an attribute analysis, in which the formulations and the addition of the flavoring were examined for each sensory attribute.

Analysis 1: Overall. The scores from the 9-point hedonic scale were summarized and means, modes, medians, standard deviations, and ranges of all formulations were calculated (Table 21). For those formulations without diacetyl, the LWLR concentration received the highest mean rating (5.03, SD = 1.71). Likewise, for those formulations with diacetyl, the LWLR/D concentration received the highest mean rating (5.28, SD = 1.70). Formulations with and without diacetyl for high concentrations of whey and rice received the lowest ratings ($\overline{X}$ = 4.28, SD = 1.91; $\overline{X}$ = 4.33, SD = 1.80, respectively).

Table 21. Overall means, standard deviations, medians, modes, and ranges of hedonic scores for the various formulations.

	HWHR	HWLR	LWHR	LWLR
Mean	4.33	4.83	4.47	5.03
SD	1.80	1.60	1.69	1.71
Median	4.30	4.70	4.40	5.10
Mode	4.00	5.00	3.00	6.00
Range	1 to 9	1 to 8	1 to 9	1 to 8
	HWHR/D	**HWLR/D**	**LWHR/D**	**LWLR/D**
Mean	4.29	4.97	4.35	5.28
SD	1.91	1.74	1.80	1.70
Median	4.30	5.10	4.40	5.90
Mode	5.00	6.00	3.00	6.00
Range	1 to 9	1 to 8	1 to 9	1 to 9

A two-factor (formulation X flavoring condition) ANOVA with repeated measures was used to analyze the overall effects of the beverage. Data showed that formulations differed significantly ($F_{3,408} = 10.136$, $p < .01$) and flavoring differed, although not significantly (Fig. 3).

Subsequent multiple comparison t tests were performed on the overall means of the formulations (Fig. 4). Results indicated that the formulation without flavoring with both low whey and rice concentrations (LWLR) was significantly preferred over concentrations of LWHR ($t_{51} = 2.071$, $p < .05$), HWLR ($t_{51} = 2.125$, $p < .05$), and HWHR ($t_{51} = 2.181$, $p < .01$. The concentrations of low whey and low rice with flavoring (LWLR/D) resulted in similar findings wherein the LWLR/D product was significantly preferred over LWHR/D ($t_{51} = 2.217$, $p < .05$), HWLR/D ($t_{51} = 2.067$, $p < .05$), and HWHR/D ($t_{51} = 2.181$, $p < .05$). These data strongly suggest that the panelists preferred lower concentrations of whey and rice than higher concentrations of either whey or rice.

A comparison of the scores for HWLR and other products revealed that HWLR was significantly preferred over HWHR ($t_{51} = 2.125$, $p < .05$) and LWHR ($t_{51} = 1.925$, $p < .05$). Similarly, with flavoring, the HWLR/D beverage was significantly preferred over HWHR/D ($t_{51} = 1.986$, $p < .05$) and LWHR/D ($t_{51} = 2.148$, $p < .05$). When the scores are plotted, it is seen that the panelists preferred higher concentrations of whey over higher concentrations of rice (Fig. 5). In addition, the panelists preferred flavoring (diacetyl) over no flavoring with high concentrations of whey ($t_{51} = 1.750$, $p < .05$), and they preferred no flavoring with high concentrations of rice ($t_{51} = 2.000$, $p < .05$).

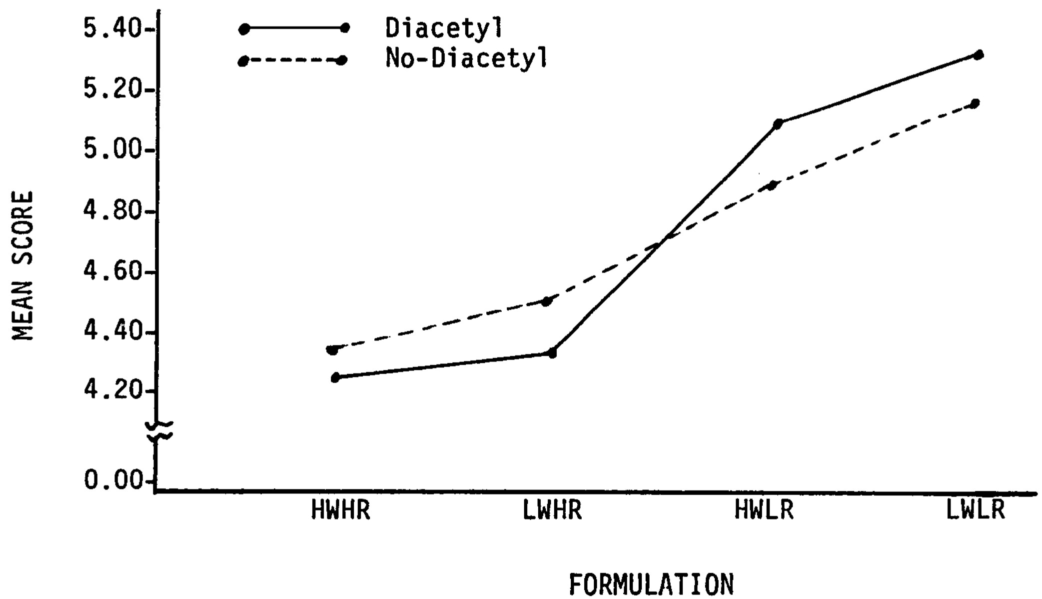

Figure 3. Overall mean hedonic scores of formulations (HWHR, LWHR, HWLR, LWLR) by flavoring (Diacetyl, No-Diacetyl).

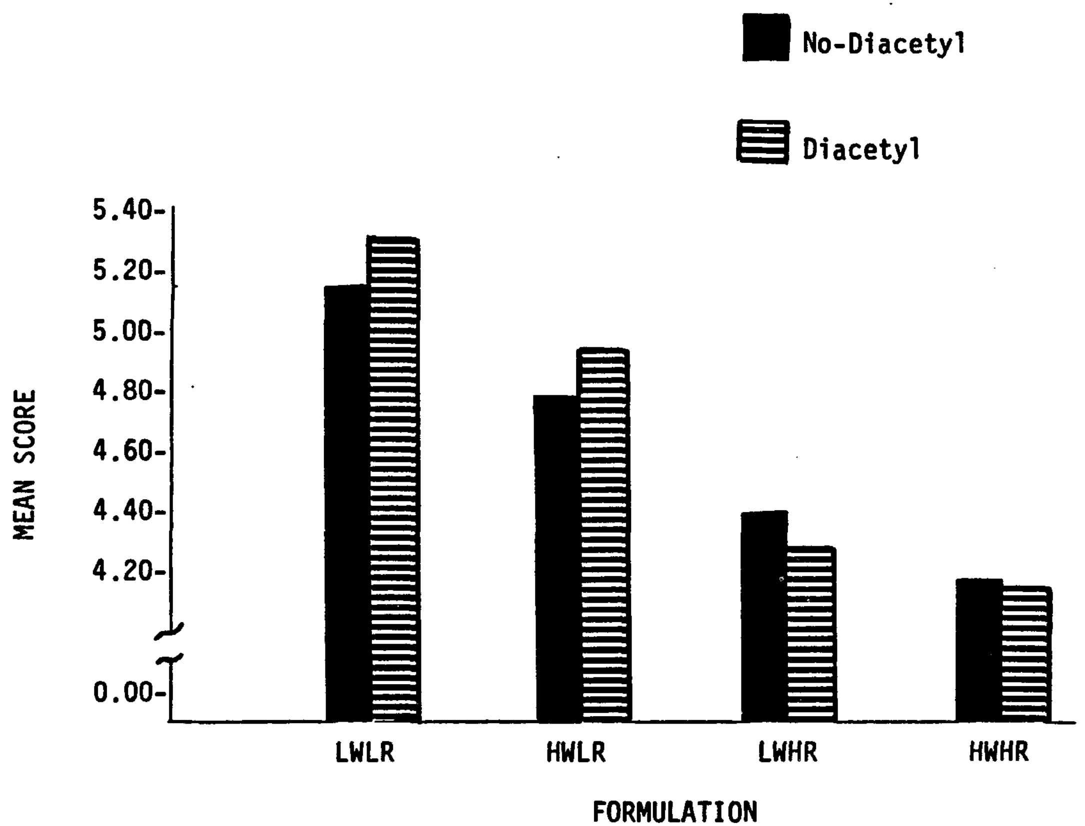

Figure 4. Mean scores of formulations (LWLR, HWLR, LWHR, HWHR) with and without diacetyl.

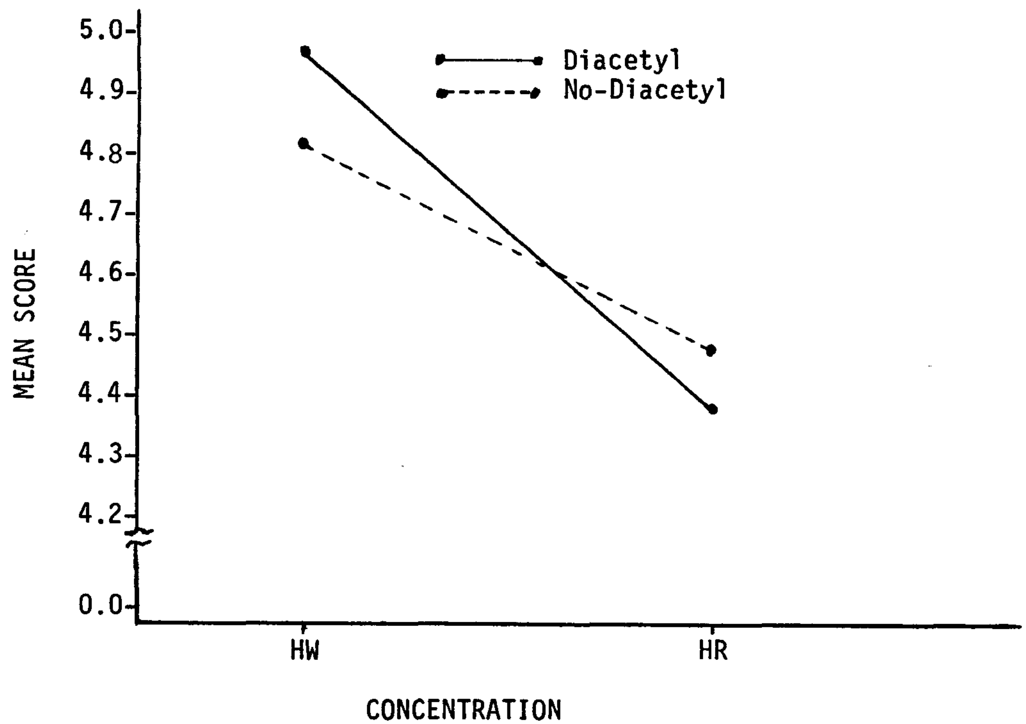

Figure 5. Overall Mean hedonic scores for overall acceptability of the various high concentration (High Whey, High Rice) beverages with and without flavoring (Diacetyl, No-Diacetyl).

Analysis 2: Sensory Attributes. The means, standard deviations (Table 22), medians, modes, and ranges (Table 23) of the scores were computed for each sensory attribute (acceptability, flavor, viscosity, appearance, texture), by formulations (HWHR, HWLR, LWHR, LWLR, HWHR/D, HWLR/D, LWHR/D, LWLR/D). For those formulations with diacetyl, the LWLR/D concentration received the highest mean for texture ($\bar{X}$ = 5.62, SD = 1.56) and in those without diacetyl, the LWLR product had the highest mean ($\bar{X}$ = 5.27, SD = 1.69) score for viscosity. The LWLR/D beverage also received the highest median for texture (6.5) and the highest mode for flavor. The lowest means were for the flavor of HWHR/D ($\bar{X}$ = 4.12, SD = 2.03) and acceptability of HWHR ($\bar{X}$ = 4.13, SD = 1.83).

Intra-sensory attribute correlation coefficients were computed for each formulation (Table 24). All correlation coefficients are greater than 0.90. The highest correlations were found between acceptability and flavor (r = 0.99) in the LWLR formulation, acceptability and flavor (r = 0.99) in the LWHR product, acceptability and viscosity (r = 0.99) in the LWLR/D beverage, and acceptability and viscosity in the HWHR formulation (r = 0.99). These high relationships suggest that the flavor and viscosity of the beverage strongly influence the overall acceptability of the beverage.

A two-factor (formulation x flavoring condition) ANOVA with repeated measures was calculated for each attribute. Results indicated that flavor showed a significant interaction between formulations and diacetyl ($F_{3,416}$ = 8.991, $p < .01$) (Fig. 6). Other attributes did not indicate significant interactions, but did reveal significant variation

Table 22. Hedonic score means and standard deviations of the sensory attributes of the various formulations.

	HWHR	HWLR	LWHR	LWLR	HWHR/D	HWLR/D	LWHR/D	LWLR/D
Acceptability	4.13[a]	4.58	4.35	4.96	4.17	4.88	4.25	5.17
	(1.83)[b]	(1.64)	(1.69)	(1.69)	(1.93)	(1.74)	(1.89)	(1.79)
Flavor	4.27	4.48	4.35	4.96	4.12	4.71	4.25	5.15
	(1.90)	(1.82)	(1.62)	(1.79)	(2.03)	(1.95)	(1.94)	(1.91)
Viscosity	4.23	5.04	4.29	5.27	4.13	5.13	4.19	5.27
	(1.98)	(1.58)	(1.90)	(1.69)	(2.04)	(1.64)	(1.95)	(1.72)
Appearance	4.48	4.90	4.67	4.90	4.63	5.00	4.62	5.20
	(1.51)	(1.52)	(1.55)	(1.63)	(1.60)	(1.60)	(1.42)	(1.50)
Texture	4.52	5.17	4.71	5.06	4.38	5.13	4.44	5.62
	(1.77)	(1.44)	(1.70)	(1.76)	(1.95)	(1.75)	(1.82)	(1.56)

[a] Mean

[b] Standard deviation

Table 23. Hedonic score medians, modes, and ranges of the sensory attributes of the various formulations.

		HWHR	HWLR	LWHR	LWLR	HWHR/D	HWLR/D	LWHR/D	LWLR/D
	M	4.0	4.0	4.0	5.0	4.0	5.0	4.0	6.0
Acceptability	m	5.0	4.0	3.0	6.0	4.0	6.0	3.0	6.0
	R	1 to 8	1 to 8	1 to 8	1 to 8	1 to 9	1 to 8	1 to 8	1 to 8
	M	4.0	4.5	4.0	5.0	4.0	5.0	4.0	6.0
Flavor	m	4.0	3.0,5.0	3.0	6.0	6.0	6.0	3.0,6.0	7.0
	R	1 to 9	1 to 8	1 to 8	1 to 8	1 to 9	1 to 8	1 to 7	1 to 9
	M	4.5	5.0	4.0	5.5	4.0	5.0	4.0	6.0
Viscosity	m	5.0	6.0	3.0	6.0	4.0	6.0	3.0	6.0
	R	1 to 8	2 to 8	1 to 8	1 to 8	1 to 9	1 to 8	1 to 8	1 to 9
	M	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Appearance	m	4.0	5.0	5.0	5.0,6.0	5.0	5.0	5.0	5.0
	R	1 to 8	1 to 8	1 to 8	1 to 8	1 to 9	1 to 8	1 to 8	1 to 8
	M	5.0	5.0	5.0	5.0	4.5	5.5	5.0	6.5
Texture	m	5.0	5.0	4.0	5.0,6.0	5.0	6.0	5.0	6.0
	R	1 to 8	2 to 8	1 to 9	1 to 8	1 to 9	1 to 8	1 to 9	3 to 9

M = Median
m = Mode
R = Range

Table 24. Correlation coefficients of the sensory attributes for the various beverages.

Beverage		Flavor	Texture	Viscosity	Appearance
HWLR	Acceptability	0.96	0.96	0.94	0.93
	Appearance	0.94	0.95	0.95	----
	Viscosity	0.96	0.94	----	----
	Texture	0.97	----	----	----
HWHR	Acceptability	0.97	0.96	0.99	0.96
	Appearance	0.95	0.96	0.95	----
	Viscosity	0.97	0.98	----	----
	Texture	0.96	----	----	----
LWLR	Acceptability	0.99	0.97	0.96	0.98
	Appearance	0.97	0.97	0.96	----
	Viscosity	0.97	0.97	----	----
	Texture	0.97	----	----	----
LWHR	Acceptability	0.99	0.95	0.96	0.92
	Appearance	0.93	0.95	0.93	----
	Viscosity	0.96	0.96	----	----
	Texture	0.95	----	----	----
HWLR/D	Acceptability	0.96	0.96	0.95	0.94
	Appearance	0.94	0.95	0.98	----
	Viscosity	0.96	0.98	----	----
	Texture	0.97	----	----	----
HWHR/D	Acceptability	0.97	0.98	0.98	0.95
	Appearance	0.92	0.94	0.94	----
	Viscosity	0.97	0.97	----	----
	Texture	0.97	----	----	----

Table 24. Continued.

Beverage		Flavor	Texture	Viscosity	Appearance
LWLR/D	Acceptability	0.96	0.95	0.97	0.94
	Appearance	0.94	0.92	0.94	----
	Viscosity	0.96	0.96	----	----
	Texture	0.96	----	----	----
LWHR/D	Acceptability	0.97	0.97	0.99	0.94
	Appearance	0.92	0.95	0.94	----
	Viscosity	0.98	0.96	----	----
	Texture	0.95	----	----	----

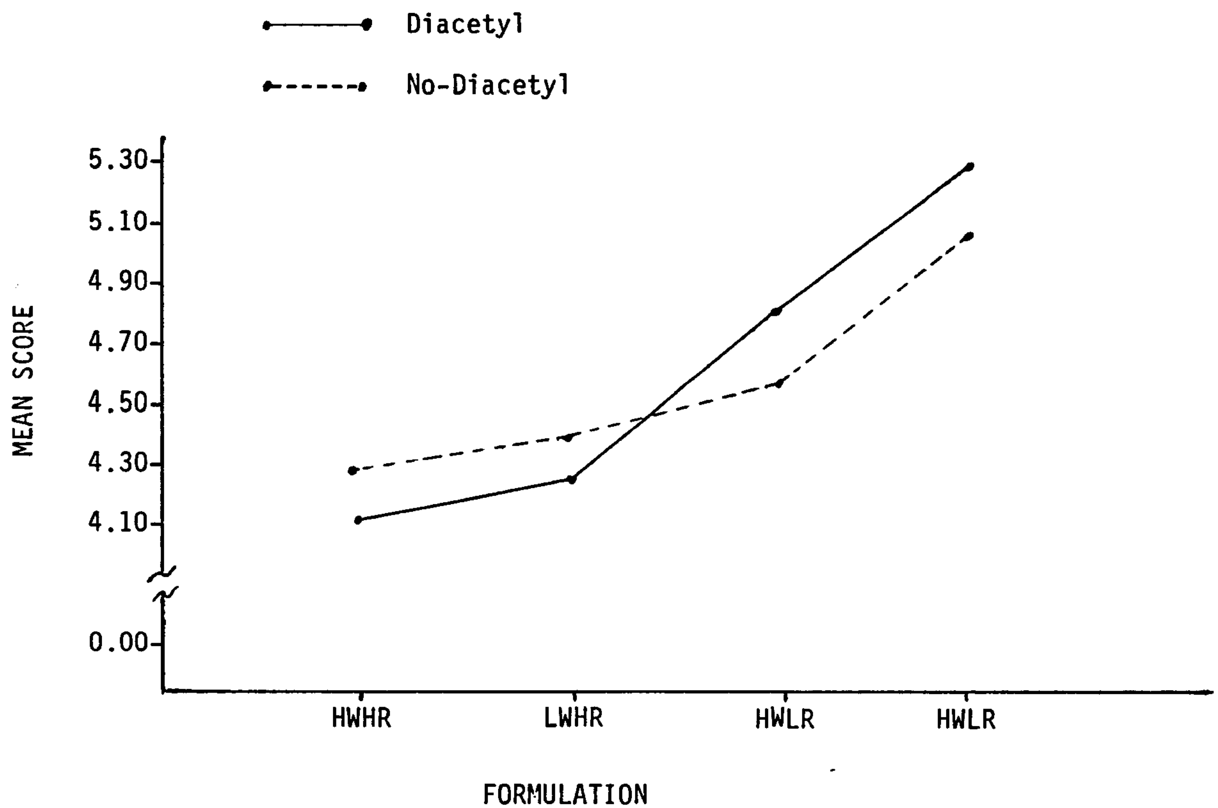

Figure 6. Mean hedonic scores of various formulations (HWHR, LWHR, HWLR, LWLR) by flavoring (Diacetyl, No-Diacetyl) for flavor attribute.

among the formulations. For example, acceptability shows a significant formulation effect ($F_{3,103}$ = 5.816, $p < .01$) (Fig. 7). A subsequent Duncan Multiple comparison test revealed that the significant difference was found between the LWLR and HWHR beverages ($p < .03$).

These data suggest that the panelists preferred lower concentrations of whey and rice over higher concentrations. In addition, flavor and viscosity apparently had the strongest influence on beverage acceptability. However, the intra-attribute correlations and small standard deviations found among the attributes would suggest that the panelists scored each attribute on the basis of overall flavor.

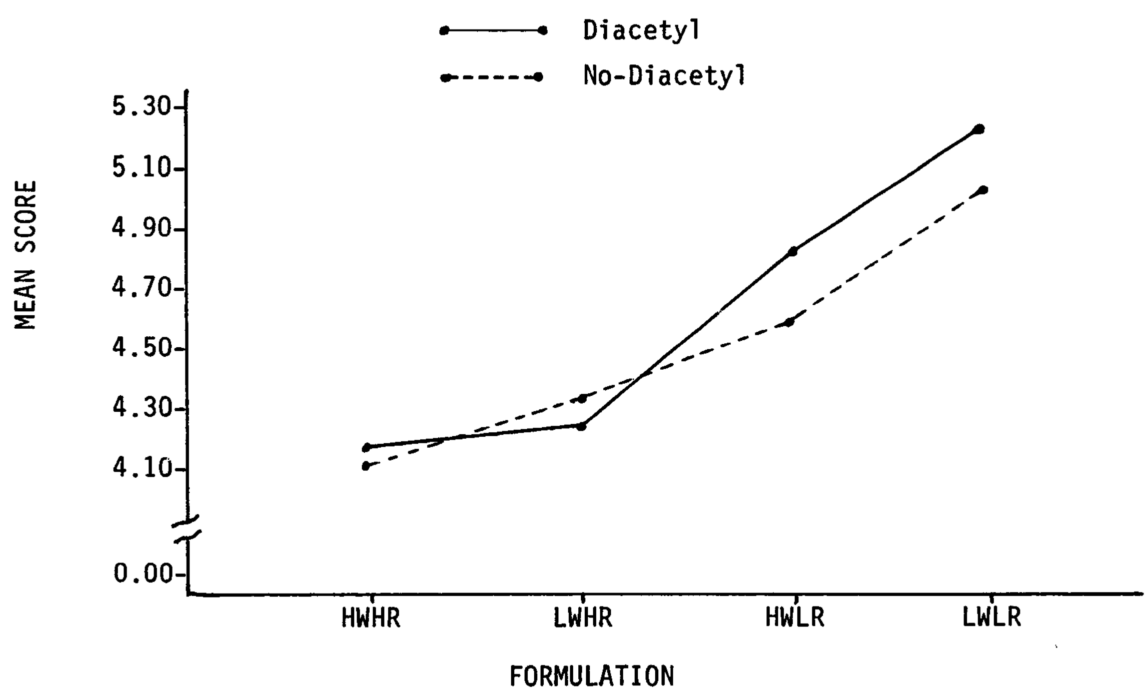

Figure 7. Mean hedonic scores of various formulations (HWHR, LWHR, HWLR, LWLR) by flavoring (Diacetyl, No-Diacetyl) for overall acceptability.

CHAPTER 5

CONCLUSIONS

The purpose of this study was to produce a product that is similar to a Horchata beverage common in Mexico that has as a principal base rice and milk. The principal ingredients for the beverages of this study were fluid cottage cheese whey and puffed rice. Although the chemical analyses and the sensory evaluations were acceptable, some adjustments in the processing techniques for these beverages could improve overall product acceptability.

For example, when diacetyl was added to the whey/rice mixtures, it produced feather-like particles that floated to the surfaces of the beverages. This condition might be corrected with a better homogenization process. Another example is that the cinnamon used in the beverage formulations was coarsely ground. As a result, it precipitated when it was added to the mixtures, and this sediment made the beverages less appealing. This condition could have been minimized by using a finely ground cinnamon or an extract.

Beverage stability could also be improved. After only five days of refrigeration, most of the beverages' ingredients had undergone some separation. Since this study did not use any type of stabilizer in the formulations, future research should evaluate this ingredient. The use of a stabilizer could also improve the viscosity of the beverages. Future research may also investigate the effects of different flavorings (e.g., citrus fruits, chocolate) to improve the flavor and color of the beverages.

From the sensory evaluation, three major conclusions can be drawn. First, intra-attribute correlations of overall acceptability suggest that the untrained panel was strongly influenced by the flavor and viscosity of the beverages. Perhaps a trained panel would have scored the beverages more objectively, since they would not have used one sensory attribute to influence another. Second, data indicate that the panelists preferred beverages with low concentrations of whey and rice with diacetyl over all other beverages, followed by preference for low concentrations of whey and rice without diacetyl. Thus, the higher overall acceptability ratings between these beverages suggest that preference was made on the basis of the diacetyl flavor. Perhaps a different flavor (such as pineapple, chocolate, etc.) would have produced even higher scores. Third, data indicate that the panelists preferred beverages containing high concentrations of whey over high concentrations of rice. This would suggest that the higher concentrations of rice strongly influenced the ratings of flavor, viscosity, and overall acceptability. Comments such as, "too thick"; "looks like medicine"; "color is funny"; etc., are reflected in the ratings of each attribute and appear more often on the scoring sheets for those beverages containing high concentrations of rice. Since the primary use of puffed rice is for breakfast foods, perhaps some additional comment such as, "this is a breakfast drink" would have produced different scores. In addition, a younger panel may have scored the beverages higher.

Nevertheless, the protein quality of all the beverages was high. In fact, the beverage with the lowest essential amino acid content was considerably higher than the recommended values of the Food and Agriculture Organization. This suggests that any of the beverages could be used as an alternative to soft-drinks which have very marginal nutritional quality. These beverages provide an alternative to the expensive disposal of whey as waste, by returning this product to the human food chain.

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