UNIVERSITY OF ALBERTA

TECHNICAL, NUTRITIONAL, AND SENSORY INVESTIGATIONS OF WHEY-BANANA BEVERAGES

by

SOPHIA AKOLEIT SHEKILANGO

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
FOOD SCIENCE AND TECHNOLOGY

DEPARTMENT OF AGRICULTURAL, FOOD AND NUTRITIONAL SCIENCE

EDMONTON, ALBERTA
SPRING 1996

ISBN 0-612-18366-1

Canada

University of Alberta

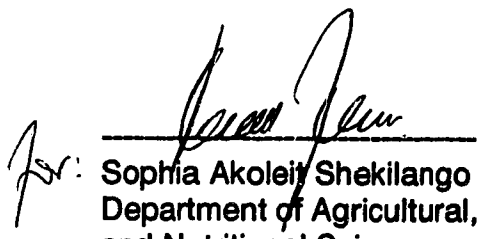
Library Release Form

Name of Author: Sophia Akoleit Shekilango

Title of Thesis: Technical, Nutritional, and Sensory Investigations of Whey-banana Beverages

Degree: Master of Science

Year this Degree Granted: 1996



Sophia Akoleit Shekilango
Department of Agricultural, Food and Nutritional Science
University of Alberta

Date submitted: August 15, 1996

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FACULTY OF GRADUATE STUDIES AND RESEARCH

THE UNDERSIGNED CERTIFY THAT THEY HAVE READ, AND RECOMENDED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH FOR ACCEPTANCE, A THESIS ENTITLED **TECHNICAL, NUTRITIONAL, AND SENSORY INVESTIGATIONS OF WHEY-BANANA BEVERAGES** SUBMITTED BY **SOPHIA AKOLEIT SHEKILANGO** IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF **MASTER OF SCIENCE IN FOOD SCIENCE AND TECHNOLOGY.**

Dr. Pavel Jelen (Supervisor)

Dr. Eileen LeBlanc

Dr. Leonard Bauer

January 05, 1996

Abstract

Possible utilization of two nutritional waste products, whey and bananas, was investigated. Two thirst-quenching prototype beverages were produced: a whey-banana shake and a whey-banana juice. The formula 3:2 of whey to banana puree was found to be suitable in formulating these beverages.

In controlling the enzymatic browning, there was no significant difference ($p \leq 0.05$) between separately heating puree at 80°C for 2 minutes and heating the puree by directly adding boiling whey to reach the same temperature and holding for the same time. In the production of the whey-banana juice, there was a substantial amount of sediment harvested. Upon centrifugation, juices from unheated control whey (CW) produced up to 50% (w/w) of sediment. Analysis of the sediment showed that it largely contained carbohydrates, mainly starch, but also lactose, sucrose, glucose and fructose. Minerals such as Ca, Na, K, Mg and S were also found.

Technical problems like sedimentation, viscosity of the shakes and the juices, and turbidity of the juices were reduced by the process of heating the skim milk before preparation of the whey (HW) and homogenizing the shakes. The colour (lightness) of the juice was improved as a result of both of these processes. The addition of xanthan gum produced a shake that was visually stable for the first 24 hours, but which separated on standing.

The preliminary sensory evaluation indicated the whey-banana juices to be preferred to the whey-banana shakes, especially the products made from heated whey (HW). Further evaluation of the juices using Free Choice Profiling with Canadian and African panels revealed the drink made with whey from heated milk; puree heated by boiling; and not homogenized; to be the most preferred product. There was no cultural

difference observed in the results of the sensory evaluation. However, a language barrier was noticed in the vocabulary development session.

Using sensory evaluation, the addition of a stabilizer to the shakes resulted in decreased banana flavour and increased thickness.

Acknowledgement

Five days after the successful defense of this thesis, the author was diagnosed with a fatal illness to which she succumbed on March 11, 1996. The goal of Sophia Shekilango, a Commonwealth Scholar from Tanzania, was to obtain knowledge that could be utilized to develop the domestic food processing industry in her native country and to improve the nutritional status of Tanzanian children. This project was designed and executed to meet her objectives.

Coming from a country where women constitute less than ten percent of University graduates, she was living proof that a scholar should not be defined only by academic pursuits. Her interests in social and women's issues complemented her work in the laboratory and are in part reflected in this thesis. As presented here, the results of her research efforts on using the native supply of bananas in a new and unconventional way illustrate the perseverance and the inquisitive mind that could have contributed significantly to technical as well as social development for Tanzania.

By executing the final corrections and changes required for successful completion of this work, our desire was to honour the unfinished commitments, visions and goals of Sophia Shekilango. Special acknowledgements are expressed to Dr. Eileen LeBlanc and Mr. Galen Bagdan for their editorial assistance in producing this final copy which, as Sophia would undoubtedly have done, is dedicated to Sophia's family, in particular to her mother Zippora and to her son Madiwa.

Prof. P. Jelen
Academic Advisor
Edmonton, August 8, 1996

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CHAPTER 1: INTRODUCTION

1.1 Nutritional waste problem

Worldwide, there is a large segment of population that is still suffering from a lack of adequate food while others are discarding nutritious food as waste. Wastage of food can occur on the farm, in storage, processing, distribution and consumption. Of all the food produced in the United Kingdom, 25% is wasted, with the major waste occurring on the farm (Robin, 1976). This food waste causes nutritional and economical losses as well as pollution of the environment. The two main ways of reducing nutritional food waste are: utilizing the waste in food processing and finding ways to consume the food product before it spoils. Many waste products, though nutritious, have been shown to have specific flavour characteristics which might have an effect on the flavour and quality characteristics of a final product. For example, Yean *et al.* (1994) recovered the proteins from water used in the production of fish balls and utilized them in fish crackers. Two other examples of nutritious products that are wasted or discarded are bananas and whey.

1.2 Bananas

Bananas (*Musa* spp.) are tropical fruits that play an important role in the human diet as a source of protein, calories, essential vitamins and minerals (Ihekoronye & Ngoddy, 1985). In Tanzania, as well as in other developing countries, tropical fruits like bananas are seasonal and are normally harvested during peak periods. However, this fruit deteriorates quickly due to its perishable nature. Also, inadequate indigenous preservation methods cannot meet the volume of production. Tanzania is among the leading banana producing countries in Africa. It has been estimated that Tanzania produced 1,000,000 tonnes of bananas in 1985 (United Nations, 1987), as shown in Table 1.1.

Table 1.1 Banana production and utilization by country in Africa, 1985[1]

	Production ('000t)	*Utilization ('000t)*		
Country	*Total*	*Export*	*Eaten*	*Processed*
Burundi	980.0	-	294.0	656.6
Ghana	10.0	-	9.0	-
Ivory Coast	135.0	75.0	29.0	-
Kenya	142.0	-	120.7	-
Malawi	13.5	-	12.2	-
Tanzania	1,000.0	-	700.0	100.0
Uganda	420.0	-	357.0	-
Zaire	325.0	-	292.5	-
Africa (total)	4,305.5	177.5	2,788.8	762.2

[1] Source: United Nations, 1987

Neighbouring countries, like Burundi and Uganda, where bananas are a staple food, are also major producers. Up to 50% of total production is wasted depending on the time of year. Table 1.2 shows the harvest and disposal in Nkwenda, a typical Tanzanian village. In the period June-August, approximately 39-51% of the total banana production was wasted.

Table 1.2 Banana harvest and disposal in Nkwenda Village, Karagwe District, Tanzania[1]

Month	*Bunches harvested*	*Method of disposal (%)*		
		Eaten	*Sold[2]*	*Wasted*
January	1825	66	19	15
February	1827	66	22	12
March	2557	47	30	23
April	2555	47	30	23
May	2556	47	29	24
June	2558	47	14	39
July	4745	27	28	45
August	6573	18	31	51
September	4748	26	37	37
October	2921	42	28	30
November	1461	82	13	5
December	2191	54	27	19
Total (12 months)	36,517	40	28	32

[1] Adapted from Tibaijuka, 1985.
[2] Including bananas paid to labourers as wages.

The modern preservation methods of refrigeration and modified atmosphere packaging are technically and economically not feasible in a country

like Tanzania, due to the high costs of implementation and expertise needed for their use. Presently, bananas may be processed into a puree or a powder, as well as canned, dried, frozen, or fermented (Stover & Simmonds, 1987).

Bananas are suitable for adding flavour to products and for regulating moisture, adding body and sweetness, modifying flavours, and cutting acid notes in fruit beverages. Bananas in Tanzania are consumed either as a ripe fruit, or cooked or dried as a banana crisp. They are often used in making banana beer, banana pancakes and banana flour (Macku & Jennings, 1987; Mariott & Lancaster, 1983; Simmonds, 1966). The main components of banana are shown in Table 1.3.

Table 1.3 Proximate composition of bananas (%w/w)[1]

Component	*Ripe banana (AAA group)*[3]	*Unripe plantain*[2] *and cooking banana (AAB and ABB)*[3]
Water	71-78	57-63
Carbohydrate	16-24	29-35
Lipid	0.2	0.2-0.3
Crude protein	1.2	1.0-1.2
Fibre	3.0-4.0	6.0-7.0
Ash	0.8	0.8-1.0

[1] Adapted from Mariott & Lancaster, 1983.
[2] Plantain is a starchy cooking banana.
[3] AAA, AAB and ABB: genetic constitutions in terms of parent species *Musa Acuminata* (A) and *Musa Balbisiana* (B).

The moisture content of banana accounts for ≥70% of the fresh weight. Bananas are a good source of carbohydrates. They constitute about 20% of the edible portion, with most sugars in ripe bananas resulting from the hydrolysis of

starch. Bananas contain 3-4% fibre and crude protein accounts for 1.2%. Fat and ash content in banana is less than 1%. The unripe banana has a lower moisture content and a higher carbohydrate content, primarily starch.

1.3 Whey

The need for utilization of whey in recent years has increased, to alleviate environmental pollution, as well as to use available nutrients contained within it. Whey, an aqueous solution containing proteins, lactose, minerals and traces of fat, remains after the manufacture of cheese or separation of caseins from milk. It contains approximately 6% total solids of which 70% or more is lactose and 11% is whey protein (Zall, 1984). A kilogram of cheese made from 10L of milk will give approximately 9L of whey as a byproduct.

Whey production on a worldwide basis was estimated as 130 million tonnes in 1988 (Sorenson, 1988), with 24.8 million tonnes being produced in underdeveloped countries (Zall, 1984). Tanzania produces only 7,000 tonnes a year (Sienkiewicz & Riedel, 1992), compared with the United States of America which produces 23.1 million tonnes of whey annually (Clark, 1987). The European Economic Community contributes 16.8 million tonnes, whereas in Australasia the production is 4.32 million tonnes a year.

Whey has been utilized in various ways with about 50% of it being utilized for human food in either liquid, dried or concentrated form. These forms of whey have been used in formulating human food and animal feed products (Jelen &

LeMaguer, 1976; Mann, 1986; Morr, 1982; Texeira *et al.*, 1983; Woychick *et al.*, 1976). However, despite these efforts much of current whey production is either disposed of as raw whey by spreading it on the land as a fertilizer, or used as animal feed. Improper disposal of whey threatens the environment due to the high biological oxygen demand (BOD) of 32,000 mg/L of O_2 (Sienkiewicz & Riedel, 1990).

Tanzania, as a developing country, is increasing the efficiency of its dairy industries. However, currently almost all of the whey which is produced is thrown onto the land or left to drain in sewage or streams. If this practice continues in the future, the problem of increased pollution and wastage of valuable dairy nutrients could become serious.

1.4 Whey-banana beverages

The majority of the population of Tanzania is affected by malnutrition, primarily protein deficiency. This is evident even in the Kilimanjaro region, despite its suitability for growing bananas and dairy production (Tanzania Food & Nutrition Centre, 1994). The concept of developing a nutritional whey-banana beverage could be a very promising area to successfully utilize both whey and bananas which might otherwise be wasted, for example:

- the wasted whey and the abundant wasted bananas could find markets as raw material and be sold cheaply to other countries of the world;

- developed countries could donate their surplus whey to banana producing countries as a form of foreign aid;
- the problem of pollution could be alleviated by decreasing the amount of raw whey discharged into waterways;
- the malnourished populations of the world could benefit from these products since they contain highly nutritious proteins from the whey and vitamins, sugars and minerals from the bananas. Whey-fruit beverages have already been found to be ideal to combat malnutrition as well as being suitable for sportsmen and children (Holsinger *et al.*, 1974; Kosikowski, 1979, 1968).

Whole whey drinks are characterized by their high nutritional value because of the presence of carbohydrates, proteins and mineral components (Kravchenko, 1987). The protein found in whey is of high nutritional value, because of the presence of all essential amino acids (Renner, 1990).

Whey-fruit beverages have been moderately successful in the past. As an example, an orange flavoured drink incorporating 33% (w/w) untreated cottage cheese whey, captured essentially half of the beverage sales at Student Memorial Union during a test period of several weeks (Nelson *et al.*, 1970). Surelli™ and Rivella™ products, popular in Switzerland, Djoez™ in Holland and Frusighurt™ in Germany are probably the most successful drinks with a whey base. Whey-fruit beverages are typically made by mixing whey with fruit juice or fruit juice concentrate. Despite the simplicity of the technology involved, frequent quality problems occur in these products that has often led to their market failure (Jelen, 1992).

Sedimentation is one of the main problems encountered in these products primarily due to heat-induced whey protein precipitation (Jelen *et al.*, 1987). The whey protein aggregation is a function of pH, concentration, temperature and calcium ions (de Rham & Chanton, 1984; de Wit, 1981; Hill, 1988). In comparing acid whey to sweet whey, acid whey is more prone to protein aggregation because it contains a higher amount of calcium (Patocka & Jelen, 1989b). The use of colloidal stabilizers has been cited as a possible way to minimize sedimentation (Jelen, 1992). Turbidity and cloudiness are also problems encountered in whey-fruit beverages; the calcium and protein components of whey have been shown to interact with the tannins and pectins from the fruit components to cause these defects (Devkota, 1991; Oh *et al.*, 1985).

The high content of lactic acid in acid whey contributes to an undesirable flavour in whey drinks and may also facilitate protein aggregation. It is important to find a proper flavour balance between the whey and the fruit flavour elements. Some drinks developed by researchers have incorporated fruits like citrus and lemon in order to achieve a balanced acid flavour note (Holsinger *et al.*, 1974). Other fruits that have been used include mango, pineapple, guava, kiwi, peach, apricot, and passion fruit (Jelen, 1992). In addition, the parameters of clarity and taste are important factors for consumer satisfaction.

Food choices made by consumers are a complex phenomenon influenced by many factors. Food selection involves personal preference and attitudes towards the attributes of the food (Shepherd, 1988). The chemical and physical

properties of foodstuffs as perceived sensorially are not the only factors that influence food selection. The success of a product in the marketplace cannot be predicted easily by sensory studies if the latter are carried out in isolation. Consumer responses are vital in the development of the product. Since sensory parameters, such as flavour, are an interaction between the product and the consumer they cannot be easily measured directly. Knowing what a consumer perceives is impossible to determine and behavioural responses must be used and interpreted in terms of sensory perception. Discrimination tests and descriptive techniques have been widely used in sensory evaluation, but these two methods alone cannot correlate the quality of the product and its success in the marketplace. The introduction of Free Choice Profiling (FCP) by Williams & Langron (1984) whereby consumer panels are used to predict the position of the product in an actual market and to represent the buyer's ideas, is an important new tool in sensory evaluation methodology.

1.5 Objectives of the research

The aim of this study was to develop several alternative and new whey-fruit beverages from acid whey and bananas. Physical, chemical, and sensory problems associated with these drinks were studied as they may lead to product failure in the consumer market.

Therefore, the main objectives were:

1. To develop two prototype whey-banana beverages using whole acid whey;
2. To investigate the effect of processing (heating of skim milk before making of whey; and homogenization of the beverages) on the viscosity, turbidity, and colour of whey-banana beverage prototypes;
3. To investigate the composition of the sediment harvested from whey-banana beverages;
4. To evaluate the market potential of a whey-banana juice product using the Free Choice Profiling method.

CHAPTER 2: LITERATURE REVIEW

2.1 Bananas

Bananas are a fruit classified in the family *Musaceae* of the order *Zingiberales*. The family *Musaceae* has two genera, *Musa* and *Eusente*, but all edible varieties are classified in the genus *Musa*. The genus *Musa* contains four sections: *Eumusa*, *Rhadoclamys*, *Australimusa*, and *Calimusa*. Most edible bananas are derived from two members of the section *Eumusa*: *Musa acuminata* and *Musa balbisiana* (Mariott & Lancaster, 1983; Palmer, 1971; Simmonds, 1966).

2.1.1 Chemical and nutritional composition of bananas

Bananas are composed mainly of water and carbohydrates; the moisture content comprises 70% of the fresh weight of banana pulp and varies widely between different cultivars and within each cultivar. Table 2.1.1 shows that the protein, lipid, and ash content are low comprising 1.2%, 0.3%, and 0.8% respectively. Nevertheless, banana protein makes a significant contribution to

human nutrition in underdeveloped areas where the population experiences protein deficiency and where bananas are eaten as a fruit or starchy staple food. Banana protein is deficient in methionine and tryptophan (Mariott & Lancaster,

Table 2.1.1 Chemical and nutritional composition of bananas (100g fresh weight, edible portion)[1]

Component	*Ripe bananas*	*Unripe plantain*[2]
Food energy (kJ)	425	476
Moisture (g)	71.6	68.2
Carbohydrate (g)	24	29
Protein (g)	1.2	1.0
Lipid (g)	0.3	0.2
Fibre (g)	3.0	6.0
Ash (g)	0.8	0.1
Ca (mg)	7	7
P (mg)	32	38
Fe (mg)	0.4	0.5
K (mg)	350	n/a
Na (mg)	4	n/a
Carotene (mg)	0.20	0.03-1.20
Thiamin (mg)	0.04	0.05
Riboflavin (mg)	0.07	0.05
Niacin (mg)	0.6	0.7
Ascorbic acid (mg)	10	20
Folic acid (mg)	0.022	0.016

[1] Adapted from Paul & Southgate, 1978.
[2] Plantain is a starchy cooking banana.

1983). The ash is comparatively rich in potassium and phosphorus, and it is a fair source of iron and calcium (Table 2.1.1). According to von Loesecke (1950), copper, iodine, manganese, zinc, and cobalt have been also identified. In contrast with other foods, the iron present in bananas is 100% utilizable for human nutrition (von Loesecke, 1950). The potassium content of bananas is variable, dependent on the cultivation conditions. Whereas most bananas float in water, those bananas deficient in potassium tend to sink (Johnson, 1979).

Bananas are an excellent source of vitamins; ascorbic acid comprises 10 mg per 100 g banana (fresh weight). In Venezuela, bananas are estimated to contribute 48% of the vitamin C to the national diet (Mariott & Lancaster, 1983). Bananas are also an important source of other vitamins, such as thiamin (B_1), riboflavin (B_2), niacin, and folic acid; each of them comprises less than 1% of the pulp fresh weight (Asenjo *et al.*, 1948; Asenjo *et al.*, 1946; Paul & Southgate, 1978). The content of vitamin B_6 is unusually high compared with its content in other food sources (Polansky & Murphy, 1966).

Bananas also contain tannin, pectic substances, cellulose, and hemicelluloses. The pectin content in bananas is about 0.3%, while cellulose comprises 2% and hemicellulose comprises 1% of the ripe fruit (Barnell, 1943; Dhua & Sen, 1989). Table 2.1.1 shows the detailed chemical composition of bananas. Bananas undergo many biochemical changes during the ripening stage. The most important biochemical changes are those concerning starch, active tannins, and skin pigments.

2.1.2 Biochemical changes in bananas during ripening

Unripe bananas have a green skin. The green coloured skin contains chlorophyll, carotene, and xanthophylls. When bananas ripen, they turn yellow. This change in colour is due to the disappearance of the chlorophyll pigment which is green in colour, revealing a yellow pigmentation caused by residual carotene and xanthophylls (Simmonds, 1966). The changes in colour serve as a guide to the stage of ripening (Table 2.1.2). When bananas are green, 20% of the fresh weight is comprised of predominantly complex carbohydrates which, during ripening, degrade to sucrose, glucose and fructose in the proportion of 66%, 14% and 20% respectively; maltose also has been detected in small amounts (Poland, 1937; von Loesecke, 1950). Mariott & Lancaster (1983) reported 20.5% of the banana starch to be amylose.

Table 2.1.2 Banana ripening stages and corresponding starch and sugar composition[1]

Maturity stage	*Colour*	*Starch (%)*	*Sugar (%)*
1	green	21.5-19.5	0.1-2.0
2	trace of yellow	19.5-16.5	2.0-5.0
3	more green than yellow	18.0-14.5	3.5-7.0
4	more yellow than green	15.0-9.0	6.0-12.0
5	green tip	10.5-2.5	10.0-18.0
6	all yellow	4.0-1.0	16.5-19.5
7	brown flecks	2.5-1.0	17.5-19.0
8	large brown areas	1.5-1.0	18.5-19.0

[1] Adapted from Mariott & Lancaster, 1983.

One of the changes taking place during ripening is the softening of the banana pulp. This softening is associated with increases in soluble pectin and decreases in insoluble protopectic substances during ripening. The pectin content in the pulp increases to 0.5% (w/w) during ripening (Palmer,1971; von Loesecke, 1950).

The concentrations of phenolic compounds such as tannins and dopamine decrease with ripening. Active tannin is one of the phenolic compounds found in bananas. The tannins are responsible for imparting astringency to the taste of bananas. The active tannin is estimated to decrease during ripening to 1/5 of its original content in green bananas (Palmer, 1971; Simmonds, 1966). Dhua & Sen (1989) found that the amount of tannins declined steadily and disappeared in the fruit pulp of the Giant Governer *Musa* Cavendish banana at the mature stage. This change in tannins is due to increased polymerization (Goldstein & Swain, 1963). The amount of tannins in banana peel also decreases with the stage of ripening, but their content is still three times higher than that in the pulp (Simmonds, 1966).

Dopamine (3,4-dihydroxyphenylethylamine) is the major substrate responsible for enzymatic browning reactions (Palmer, 1971). The enzyme polyphenoloxidase (PPO), which is present in bananas, is believed to utilize dopamine in the browning process. Palmer (1963) isolated PPO from banana pulp and used it to catalyze the reactions of variety of diphenolic substances. Palmer's results showed dopamine to be the most reactive substrate for PPO.

During ripening, the pH of the banana pulp drops from 5.4 to about 4.5.

The major acids in banana are malic, citric, and oxalic; shikimic, quinic, glycolic, glyceric, pyroglutamic, succinic, and tartaric acids are minor constituents of ripe bananas (Mariott & Lancaster, 1983; von Loesecke, 1950). Lipids and proteins undergo little change during the ripening process. However, it has been reported that ascorbic acid is destroyed quickly when banana pulp is macerated in air (Palmer, 1971; von Loesecke, 1950).

During ripening, the fruit's skin is transformed from green to yellow to yellow flecked with brown congruent with the production of a delicate aroma which is absent in the unripe fruit. The increases in development of banana flavour are due to an increase in the concentration and complexity of volatiles during ripening as the plant changes its respiration mechanism from anabolic to catabolic. McCarthy *et al.* (1964) investigated volatile production in two varieties of bananas using gas chromatography to obtain their flavour profiles. The number of peaks obtained at different stages of ripening increased with maturity. More peaks were found at maturity stage 7 (skin is yellow flecked with brown spots). The flavour of any fruit is due both to nonvolatiles (sugars, acids, and phenolics), as well as volatile organic compounds. Bananas contain at least 350 volatile components (Tressl *et al.*, 1970; Wick *et al.*, 1969), of which 80 have been identified as esters, 4 as alcohols, 23 as carbonyl compounds, and others as phenol ethers. Many constituents remained unidentified and very little is known about their contribution to aroma characteristics. Esters (isoamyl acetate, amyl acetate, amyl propionate and amyl butyrate) are known to make the main contribution to the characteristic aroma of bananas.

The sensory attributes of the major flavour compounds of banana are shown in Table 2.1.3. The processing of banana puree may lead to changes in the volatile constituents. The major carbonyl component of fresh banana, 2-hexanal, is normally absent in heated and mashed puree. Quick mashing, deaeration and heat treatment above 80°C hinders the formation of 2-hexanal (Hultin & Proctor, 1961).

Table 2.1.3 Sensory attributes and corresponding volatiles of bananas[1]

"Banana-like"	*Fruity*	*Woody or musty*	*Ethereal*
3-methyl butyl acetate	butyl acetate	methyl acetate	eugenol
amyl acetate	butyl butyrate	pentanone	elimicin
amyl propionate	hexyl acetate	butyl alcohol	methyl ethyl of eugenol
amyl butyrate	3-methyl butyl butyrate	amyl alcohol	
amyl acetate	hexyl acetate	butyl alcohol	
3-methyl butyl butyrate	3-methyl butyl acetate	hexyl alcohol	

[1] Adapted from Mariott & Lancaster, 1983 and Palmer, 1971.

2.2 Whey

Whey is the fluid obtained by separating the casein coagulum from whole milk, cream, or skim milk during cheese or casein manufacture (Zall, 1984). Whey contains lactose, whey proteins, nonprotein nitrogen, minerals, water soluble vitamins, and traces of fat. There are two types of whey: acid whey and

sweet whey, depending on the way the casein part of milk is separated. The acid whey occurs as the byproduct from the manufacture of cottage cheese or acid casein and is produced predominately by the use of mineral or organic acids, or acidification resulting from fermentation by lactic acid bacteria to a pH of 4.5-4.8. Sweet whey is the milk serum obtained by separation of casein without addition of acids, and is produced predominantly by adding rennet or other milk clotting enzymes at pH>6.0 as in most cheesemaking operations (Jelen, 1991; Sienkiwicz & Riedel,1990; Zadow, 1984; Zall, 1984, 1972).

These two types of whey differ in their mineral content and residual acidity. The main component, other than water, of both is lactose, while protein, ash, fat and lactic acid each constitute not more than 1% (w/w). Heating, centrifugation, and/or homogenization used in milk pretreatment processes account for the differences in composition of the whey. The proximate composition of the two principal types of whey is shown in Table 2.2.1. Lactose, the most abundant material in either whey, constitutes approximately 4.9%. A lower amount of lactose in acid whey is due in part to it being lost in the first stage of the fermentation to lactic acid (Jelen, 1991). Protein constitutes about 0.7% of the whey, but this fraction may include 0.2-0.3% of nonprotein nitrogen which is included as whey protein. Whey also contains calcium, phosphate, citrate, sodium, potassium and chloride. Acid whey contains high amounts of calcium and phosphorus as a result of the solubilization of the calcium-phosphate complex of the casein micelle in the acid pH range (Jelen, 1991). The different minerals and the variable acid content contribute to the differences in

the properties of the two types of whey.

Table 2.2.1 Proximate compostion of acid whey and sweet whey (%w/w)[1]

Component	*Acid whey (%)*	*Sweet whey (%)*
water	93.5	93.7
lactose	4.90	4.95
lactic acid	0.40	0.05
milk fat	<0.10	0.50
protein	0.75	0.80
ash	0.80	0.50
pH	4.3-4.6	5.7-8.3

[1] Adapted from Cotton, 1976 .

2.2.1 Whey proteins

Whey proteins constitute about 20% of the total protein fraction of cow's milk, the other 80% being caseins. The most important whey proteins, or serum proteins, are β-lactoglobulin (β-Lg), α-lactalbumin (α-La), bovine serum albumin (BSA), and immunoglobulins (Ig). In addition, whey contains other proteins such as lactoferrin and milk enzymes such as lysozyme, lipase, and xanthine oxidase which are all present at low concentrations (Eigel *et al.*, 1984; Marshall, 1982). The protein composition of acid and sweet whey is similar except for the significant difference in casein derived peptides (CDP) (Table 2.2.2).

Table 2.2.2 Protein compostion of acid whey and sweet whey (%w/w)[1]

Protein	*Acid whey (%)*	*Sweet whey (%)*
β-lactoglobulin (β-Lg)	54	45
α-lactalbumin (α-La)	23	18
bovine serum albumin (BSA)	6	5
immunoglobulins (Ig)	6	5
enzymes	2	2
phospholipid protein complexes (PPC)	5	5
casein derived peptides (CDP)	2	20

[1] Adapted from Pearce, 1989 .

The most abundant whey protein is β-Lg which comprises about 50% of the total serum protein in bovine milk. Regardless of the source of the whey, β-Lg exerts a dominant influence in any processing operation (Mckenzie, 1967; Morr, 1982; Swaisgood, 1982). β-Lg exists as a dimer at a natural milk pH of 6.7 because of electrostatic interactions between the amino acids Asp^{130} and Glu^{134} of one monomer with the corresponding lysyl residues of another monomer (Creamer *et al.*, 1983). β-Lg has a constrained secondary and tertiary structure described by 15% α-helix and 51% β-sheet structure (Creamer *et al.*, 1983).

Cow's milk contains at least five different genetic variants of β-Lg (Eigel *et al.*, 1984), the two most common variants being A and B. The native dimer conformation of β-Lg is sensitive to heat and pH; at temperatures below 25°C and pH values above 7.0, the protein forms octamers. As described by Creamer *et al.* (1983), most of the tertiary structure of β-Lg is maintained by two disulfide

bonds and a thiol group.

The second most important whey protein is α-La which constitutes about 20% of the serum protein in bovine milk. This protein forms a part of the lactose synthesizing system, acting as a co-enzyme in the final stage of lactose synthesis (Sienkiewicz & Riedel, 1990). α-La has a molecular weight of 14,000 daltons, contains 123 amino acids, and is rich in lysine, leucine, threonine, tryptophan and cysteine. The secondary structure of α-La consists of 26% α-helix, 14% β-sheet, and 60% unordered structure with four disulphide bonds. Two genetic variants, A and B, are common (Creamer *et al.*, 1983). Calcium is bound to α-La to stabilize the molecule against irreversible thermal denaturation (Hiraoka & Sugai, 1984). When the bound calcium is removed, the transition temperature is reduced, hence irreversibly facilitating its thermal denaturation and aggregation (Bernal & Jelen, 1984; Kronman *et al.*, 1981; Murakami *et al.*, 1982). α-La undergoes structural changes in the presence of guanidine and at elevated temperatures (Hiraoka & Sugai, 1984; Kuwajima *et al.*, 1986).

BSA, a large monomer, constitutes about 10% of whey protein. The molecular weight of BSA is 66,267 daltons; it contains 17 disulphide bonds and a thiol group. The presence of many disulphide bonds helps in the stabilization of the structure. The secondary structure of BSA contains 55% α-helix, 16% β-sheet, and 25% unordered structure (Reed *et al.*, 1975). BSA and the immunoglobulins pass into milk from blood serum through the mammary glands.

There are five types of immunoglobulins identified: IgA, IgG, IgD, IgE, and

IgM. These immunoglobulins account for about 10% of the serum proteins. To date, the functions of the immunoglobulins have not been well explained.

The proteose peptones originate from either β-casein or from fat globule membranes. The naturally occurring enzymes identified in whey are alkaline and acid phosphatases, lactoperoxidase, xanthine oxidase, catalase, superoxide dismutase, δ-glutamyl transferase, sulphydryl oxidase, amylase, lysozyme plasmin, ribonuclease, and amylase (Farkye & Imafidon, 1995; Pearce, 1989). Little information is available on the function of these enzymes except that some of them may modify the flavour of the milk.

2.2.2 Thermal properties of whey proteins

Whey proteins are sensitive to heat and their heat stability depends fundamentally on their amino acid sequence (de Wit, 1981). The protein structure and its relationship to the functional properties are important because the extent of protein denaturation significantly affects the utilization of whey as a functional ingredient. Denatured proteins may have limited solubility, a primary prerequisite for most functional uses.

Heat treatment of whey proteins often results in denaturation, loss of solubility, and aggregation (Kinsella & Whitehead, 1990). The most important factors in determining heat stability of whey proteins in milk, whey or any other dairy products are pH, ionic strength, the rate of heating and to a lesser extent the concentration of protein and lactose.

Lactose was found to reduce whey protein aggregation during heat treatment, particularly in the isoelectric pH range (Bernal & Jelen, 1985; Hillier & Lyster, 1979). Bernal & Jelen (1985) reported thermal denaturation (TD) values of 81.2±0.5°C and 82.2±0.5°C for β-Lg in simulated milk ultrafiltrate with or without lactose added, respectively. Calcium is also known to play a part in thermal properties of whey protein. Calcium interacts with the negatively charged carboxyl groups of the protein reducing the net charge to zero and thereby causing isoelectric precipitation (Elfagm & Wheelock, 1978).

BSA and Ig used to be known as the most heat sensitive of the whey proteins, followed by β-Lg and α-La (Harper & Zadow, 1984), but others have found α-La to be the most heat sensitive of the whey proteins having a denaturation temperature of about 65°C at pH 6.7 (Bernal & Jelen, 1985; de Wit *et al.*, 1983; Ruegg *et al.*, 1977). IgG fraction and other immunoglobulins are denatured when heated at 72°C for 15 seconds at pH 6.7 (de Wit & Klareenbeek, 1984; Kinsella & Whitehead, 1989), whereas BSA denaturation temperatures vary from 71.9°C at pH 6.5 to 74°C for pH 4.5 (Bernal & Jelen, 1985). The thermal properties of β-Lg are dependent on pH, calcium, the presence of chelating agents and phosphate (de Rham & Chanton, 1985). β-Lg undergoes a slight conformational change when heated to 40°C and upon further heating to 50-60°C it unfolds thereby exposing its thiol groups (Kella & Kinsella, 1988; Mckenzie, 1971). Protein unfolding increases with pH. Hegg (1980) found that the denaturation temperature of β-Lg increased from 78°C to 80°C between pH 2 and pH 4, and then progressively decreased with increasing

pH, being 78°C at pH 6; 67°C at pH 7 and 60°C at pH 8. Under these alkaline pH conditions and at temperatures greater than 70°C, the thiol group was exposed (Kella & Kinsella, 1988; Lyster, 1972) therefore accelerating disulphide interchange (de Wit, 1984). The primary products are colloidal aggregates formed by SH-SS interchange at temperatures greater than 70°C. Between 60°C and 70°C nonspecific aggregation occurs to form larger colloidal structures independent of SS bonding and yields a precipitable coagulum. α-La denatures reversibly at 65°C; however, when heating α-La for 10-30 minutes at 100°C, only 4% of the protein molecules revert back to their native state (Schnack & Klostermeyer, 1980). In addition, α-La stability also depends on pH and denaturation is more pronounced at pH<4.0 (de Wit & Klarenbeek, 1984; Kronman *et al.*, 1981).

2.2.3 Interactions of whey proteins

Heating skim milk induces physical and chemical changes in it, including interactions among the milk proteins. Specifically, β-Lg, the major component of the whey protein fraction, interacts with the κ-casein fraction when heated at ≥80°C. The degree of interaction between β-Lg depends on time, temperature of heating, concentration of proteins, and presence of salts (Singh, 1995). Calcium ions are known to promote the interactions and increases occur when pH increases from 6.3 to 7.3 (Smits & van Brouwershaven, 1980). κ-casein is also

known to interact with α-La upon heating (Shalabi & Wheelock, 1976). The interaction between these two compounds depends on the type of buffer, pH, ionic strength, and temperature (Singh, 1995). κ-casein interacts with α-La at pH 7.6 when heated at 90°C for 30 minutes (Sedmerova *et al.*, 1972). When heated together, β-Lg and α-La have been found to form a complex which then interacts with κ-casein (Singh & Creamer, 1991). When caseins are precipitated by acidification of heated milk, the whey protein content of the residual whey is substantially lower as a result of these interactions.

Whey proteins can interact, with or without heating, with certain nondairy ingredients in a product, such as pectin. High methoxy and low methoxy pectins interact with whey proteins, resulting in visual sedimentation. The presence of both protein and pectin in a 2:1 ratio resulted in the formation of a sediment in a solution containing a mixture of whey protein and pectin, thereby indicating the possible interaction of whey protein and pectin (Devkota, 1991). In solutions, particles are formed as a result of pectin-pectin and pectin-protein interactions via electrostatic forces, calcium pectate cross-linking, and hydrogen bonding that lead to a cloudy solution being formed (Mizrahi, 1979).

Tannin-protein interactions are responsible for the formation of hazes in natural beverages (White, 1957). Tannins and proteins bind together via multiple bond formation between the hydroxyl group of tannins and the carbonyl groups of proteins and peptides (van Sumere *et al.*, 1975). Hydrophobic reactions have been also suggested as important in the formation of tannin-protein complexes (Hagerman & Butler, 1980; Oh & Hoff, 1987). Tannins precipitate proteins at pH

values up to the isoelectric point of the individual protein (Oh *et al.*, 1985). The tannin-protein complex is believed to be one of the main reasons for turbidity in beverages. The concentration of salt and the pH of a solution tends to affect turbidity values. At pH 3, salt has an effect on the turbidity values, while at pH 4, higher turbidity occurs irrespective of the salt concentration. At pH 5, the salt concentration decreases the turbidity values of the solution (Oh & Hoff, 1987). Binding of a condensed tannin occurs at any pH<8. Hagerman & Butler (1978) reported that when protein conformation is more open, the protein tends to bind the tannin more strongly. The extent of turbidity is proportional to the extent of tannin-protein formation (Oh & Hoff, 1987). A high protein concentration increases the turbidity because of the increase in soluble tannin-protein complexes. BSA is known to react with tannin to form a soluble compound; this depends on the relative amount of tannins and proteins as well as on pH and salt concentration (Calderon *et al.*, 1968). The optimum interaction between BSA and tannin occurs at pH 4 (Oh & Hoff, 1987).

Milk proteins (caseins as well as whey proteins) also interact with various polysaccharides such as starches. Osman & Cummisford (1959) and Osman (1967) reported that starch pastes in milk had higher viscosity than that found in water. In addition, the properties of starch based sauces were influenced by the type of starch used and the concentration of milk proteins (Muir *et al.*, 1991).

2.3 Whey-fruit beverages

Incorporation of fruit with whey combines the nutrients from both whey and fruit for a dietetically valuable, thirst-quenching beverage that has a balanced mineral content, and a high level of calcium (acid whey contains approximately 120 mg Ca/100 mL). The development and use of whey-fruit beverages is not a new concept. The use of whey as a beverage can be traced back to ancient times (Holsinger *et al.*, 1974). Among the most successful modern whey beverages is Rivella™, developed in Switzerland in 1952. Other beverages that have been described in the literature include Bodrost™, a sparkling type, made in the former Union of Soviet Socialist Republics from pasteurized, clarified whey with the addition of sugar and raisins. Taksi™, from Holland, is a beverage which contains 80% whey, 12.8% juice concentrate, and colouring. Recently developed whey beverages marketed in Europe include Kurmolke™, Big M™ and Frusighurt™ in Germany (Jelen, 1992; Lang & Lang, 1976).

Acid whey, in the liquid or powdered form, is the type of whey used mostly in the formulation and processing of a fruit flavoured beverage because of its compatibility with a wide variety of fruit flavours. Most of the fruits which have been used have an acid character, e.g., lemon, orange, and grapefruit. Other milk-like beverages have been produced by blending whey with sugar, fruit juices, vegetable oils, and vegetables. The resulting mixture is then pasteurized, cooled, and bottled (Holsinger *et al.*, 1974). Deproteinizing the whey before

making the beverages has been used in beverages like Taksi™, Syra™ and Myra™ which originate from Holland. The common deproteinizing method is heat precipitation of whey proteins by steam injection (Sienkiewicz & Riedel, 1990). Some of the beverages which were developed from deproteinated whey still have a high nutritional value with highly reabsorbable lactose and important minerals. Sweeteners and different flavours can be added to the whey beverages like Rivella™ which uses sugar or artificial sweeteners; sometimes tartaric and citric acid have been added to mask any whey "off" flavour.

Poor flavour/flavour blends may be one cause of lack of high marketability for whey beverages when compared to other beverages (Jelen, 1992). High amounts of lactose, the pH and excess salt make whey a difficult material to use. Whey is known to contain several flavour characteristics; whey volatiles contribute principally to diacetyl flavour, and to a lesser extent to acid and brothy flavours. Other flavour notes are saltiness, astringency, bitterness and sweetness (McGugan *et al.*, 1979).

A major problem that may be encountered by whey-fruit beverages is the interaction between the calcium and protein of the whey and the fruit components such as pectin and tannin thereby resulting in turbidity, cloudiness, high viscosity and sedimentation (Devkota, 1991; Jelen, 1992; Jelen *et al.*, 1987; Mizrahi, 1979). Viscosity of whey beverages is influenced by heat, particle size, as well as the pectin and tannin content of the fruit.

2.3.1 Viscosity

Viscosity is defined as stress as a function of strain. Viscosity is an important physical property related to the quality of liquid foods. Knowledge of the rheological properties of fluid foods is essential for both product development and manufacturing process control. The rheology of a fluid is evaluated by measurement and analysis of its flow curve wherein shear stress is plotted against shear strain. Fluid products can be Newtonian, *i.e.* those fluids in which the viscosity is influenced by temperature and its composition, and is independent of shear rate. Milk, clear fruit juices, and sucrose solution have Newtonian flow characteristics. Fluids which do not follow Newtonian behaviour are called non-Newtonian fluids; their viscosities are influenced by shear rate. Non-Newtonian fluids can be divided into two categories: time dependent fluids, in which at constant temperature the apparent viscosity depends only on the shear rate; and time independent fluids, in which the apparent viscosity depends on the duration of the shear. These can be divided further into shear thickening (dilatant), where apparent viscosity increases with time; and shear thinning (pseudoplastic), where apparent viscosity decreases with time. Most non-Newtonian fluids exhibit pseudoplastic behaviour (Rao, 1987; Sheth, 1976).

The structural elements of a fluid product consist of dispersing medium (serum) and the suspended particles (pulp). These types of foods can vary widely in their rheological behaviour. Foods of plant origin such as applesauce, concentrated orange juice, and baby foods contain suspended solids in a fluid

media. Their non-Newtonian behaviour increases with the maturity of the fruit. Insoluble solids (pulp) affect the magnitude of the rheological properties, depending on particle size, shape and distribution (Mizrahi & Berk, 1970a, 1970b; Rao, 1987). Temperature has a smaller effect on cloudy juice than on clear juice (Saravacos, 1970). Pectin affects the viscosity of the serum and is one of the main causes of non-Newtonian behaviour.

The cell wall was found to be the principal element related to consistency. Whittenberger & Nutting (1957) explained that cells might be identical in quantity, but that they could differ in configuration or structural arrangement. Irregularity of cell walls can be brought about by mechanical treatment during processing, *i.e.*, forcing cell walls through passages of small clearance or through other types of shearing and tearing devices. The character of a cell wall also varies with pectin content. Pectin containing cell walls bind appreciable amounts of water and yield thicker juices. Sucrose and temperature have been found to reduce the viscosity of pectin containing solutions (Mizrahi, 1979). The apparent viscosity of concentrated whey strongly depends on the composition of the whey and the temperature treatment (Buma, 1980). Delaveau & Jelen (1979) found that whey viscosity increases at pH>6.0.

2.3.2 Homogenization

Dairy homogenization consists essentially of passing a dairy fluid through a very small orifice at high pressure and very high speed. The disruptive action

is a result of shear at the face of the valve when the product flows through the narrow passage at high velocity. The most common use of homogenization is to disrupt milk fat globules (Wilbey, 1992). Particle size and shape can be affected by the homogenization process, thus resulting in decreased sediments in fluids which contain insoluble particles. Sedimentation is related to particle size, although Kimball & Kertesz (1952), when studying the rate of sedimentation, found that not only particle size but also particle nature is responsible for sedimentation. Homogenization is reported to greatly improve consistency of a solution containing particles by converting spherical particles to elongated particles and by reducing the particle size (Luh *et al.*; 1954; Whittenberger & Nutting, 1957). Homogenization is believed to be a factor in preventing phase separation. Leonard (1980) found serum separation in tomato paste to be less pronounced after homogenization.

2.3.3 Stabilizers

Stabilizers, such as gums and proteins, are incorporated into food formulations in order to impart a wide range of characteristics to the finished product. Thickening is one of the characteristics which results in increased viscosity of the solution, thus retarding the motion of the dispersed phase in the case of suspensions containing insoluble particles. Most gums are hydrocolloids, or generally, water soluble biopolymers (usually polysaccharides) of high molecular weight. Their properties are determined by both composition

and structure of their basic units (Glicksman, 1969).

Gums are used in foods as bodifying, stabilizing, and emulsifying agents. When hydrocolloids are used as viscosity increasing agents to stabilize a food system and increase shelf stability, the selection of a proper hydrocolloid is critical. Hydrocolloids, when degraded, result in a reduction of viscosity and thereby affect the flow properties of a solution (Glicksman, 1969). Gums have been used in various beverage applications, e.g., fruit juices and drink mixes.

Xanthan gum is one of the most used food hydrocolloids by the food industry. Xanthan gum is a heteropolysaccharide produced by *Xanthomonas campestris* (Glicksman, 1969). Dried food grade xanthan gum is a cream coloured powder. The gum is soluble in hot and cold water and produces a solution profile with excellent solubility under both acidic and alkaline conditions. The viscosities of xanthan gum solutions are very high yet remain insensitive to pH over the range of 1.5-13.

Incorporating a gum into a food formulation can lead to marked changes in the perceived flavour and texture of the product (Walker, 1984). These changes may lead to consumer acceptance or rejection of the product. No food ingredient is likely to be successful if it has an adverse effect on either flavour or aroma. The rheology of food may also greatly affect the perception of flavour. Gums have a significant effect on flavour and aroma perception. This may occur indirectly via immobilization of water whereby vapour pressure of water soluble aroma volatiles is increased. Launay & Pasquet (1982) found that a change in perceived sweetness correlated well with increasing viscosity. In real food, the

presence of a gum can inhibit the diffusion of sugars, salts, acids and bitter agents to different extents, and so it is likely to result in complex effects on the flavour profiles. The acceptance of a product depends on both its chemical and physical properties. In order for the product to be successful in the marketplace, these attributes have to interact with awareness, needs, and attitudes of the person consuming it.

2.4 Sensory evaluation

The science of sensory evaluation is defined as the scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch, and hearing (Institute of Food Technologists, Sensory Evaluation Division, 1981). Different types of tests are used in sensory evaluation in relation to the problem under investigation. The three groups of methods used are discrimination, descriptive, and affective (acceptance/preference) tests. Discrimination tests are used when determining the difference and sensitivity levels between/among products. Descriptive tests are used to characterize and/or compare samples with respect to one or more specific characteristics, e.g., attribute rating, texture and flavour profiling by a trained panel (Meilgaard *et al.*, 1991). Affective testing is normally used to determine the preference of the panelist in their liking of the product or acceptance to use the product. Acceptance, preference, and consumer testing are synonymous with

affective tests. In affective testing, the panel used should be composed of consumers who are users of the product category, and unlike discriminatory or descriptive panelists, these judges are untrained (Penfield & Campbell, 1990)

2.4.1 Sensory profiling

Sensory profiling, using different types of descriptive tests, started over 40 years ago (Meilgaard *et al.*, 1991). Descriptive analysis provides a detailed description of the perceived qualitative and quantitative characteristics of a food product. Sensory profiling of a food product started with the technique known as the Flavour Profile Method (FPM) (Cairncross & Sjostrom, 1950). The practical application of FPM required the analysis to be conducted by a group of experts, highly trained tasters who derived a common terminology and frame of reference for the products under test. When in consensus, they evaluated the product for its aroma and flavour, recorded the "character notes", and then agreed on each character note score (Power, 1984). This method allowed use of a small panel, but unless the members were highly trained, there was a lack of consistency, a lack of reproducibility, difficulties in discriminating specific character note differences, and, of course, no statistical treatment of data. Hence, these limitations led to the development of the technique of Quantitative Descriptive Analysis (QDA) (Stone & Sidel, 1985).

QDA differed from FPM in terms of panel members; the panelists are selected based on their ability to discriminate differences in sensory properties,

then trained, and a comprehensive list of vocabulary is derived from terminology developed by individual panelists for the product(s) under evaluation. The vocabulary in QDA is more extensive as it evaluates the visual, textural, and flavour attributes and these are then scored independently. Each panelist evaluates each product one at a time and does not discuss the data with other panelists. The data obtained in QDA are analyzed statistically. QDA is a very successful descriptive method and continues to be used extensively; however, it requires a considerable amount of time for the sensory analyst to recruit, screen, and train the panelists to evaluate objectively specific products in a consistent manner. Because of these reasons, and the high cost associated with QDA, some researchers have chosen to use an alternative method: Free Choice Profiling (Meilgaard *et al.*, 1991; Stone & Sidel, 1985; Stone *et al.*, 1974).

2.4.2 Free Choice Profiling

Free Choice Profiling (FCP) is a relatively new sensory evaluation technique developed at the Agriculture and Food Research Council in the UK by Williams & Langron (1984). The FCP technique describes and quantifies sensory differences among products and panelists. FCP differs from conventional QDA because the panelists are consumers who describe the perceived qualities of the products using their own individual list of terms rather than a common, prepared score card. The list of vocabulary developed can be totally different among the panelists (Williams & Arnold, 1985). FCP assumes

that panelists do not differ in the way they perceive the sensory characteristics of the product (Jack & Piggott, 1991). Products tested can either be evaluated for a single characteristic such as was done in the evaluation of rum (Piggott *et al.*, 1992) or for more than a single characteristic as in the evaluation of the aroma of coffee (Williams & Arnold, 1985). FCP is a new technique that is being used increasingly by researchers to evaluate a variety of products, e.g., port wines (Williams & Langron, 1984), meat patties (Beilken & Griffiths, 1990), texture of cheese (McEwan *et al.*, 1989), processed meat (Beilken *et al.*, 1990), irradiated turkeys (Lynch *et al.*, 1991), whiskies (Guy *et al.*, 1989), and yogurts (Dijksterhuis & Punter, 1990).

In FCP, the panelists are selected from the intended naïve consumers of the product, *i.e.*, people from the target market. The criteria used for choosing panelists has differed among the above researchers, but in general, the choice has been based on interest, health, attitude, level of confidence, responses given in the questionnaire when recruiting the panelists, and their ability to discriminate and verbally communicate their perceptions (Lyon, 1987; Marshall, 1982; Marshall & Kirby, 1988; Oreskovich *et al.*, 1991). In addition, in some instances, they have been chosen based on the purpose of the study (e.g., beer consumers) or the group of interest, e.g., males versus females (Williams & Langron, 1984).

The size of the panel has also varied in the different studies described, with the panel size reported ranging from 8 to 20 (Oreskovich *et al.*, 1991) yet on a few occasions, a large number of panelists was used. Piggott *et al.* (1990)

used 61 panelists for the evaluation of whiskies, whereas Gains & Thomson (1990) used 20 panelists for their evaluation of beer. These reports show a vast difference of opinion with regard to appropriate panel size, and there is some lack of clarity in how the actual panel work was carried out. Nevertheless, use of a large number of untrained panelists reduces the variability of the results.

In FCP, each individual has to develop his/her vocabulary according to the attributes he/she perceives. The panel in FCP can profile the product without training (Williams & Arnold, 1985) or with a little training in terms of introduction to the procedure (McEwan *et al.*, 1989) and in the usage of the scale as was done in the evaluation of whiskies (Piggott *et al.*, 1990). In FCP, the panelists merely have to be objective in using line scales and using their developed vocabulary consistently. Some level of training can increase the reproducibility of the results and the specifics of descriptors generated (Gains & Thomson, 1990; Williams & Langron, 1984).

The scale used in FCP has to be unstructured and unidirectional in nature. However, scales used in FCP have differed among researchers. Williams & Langron (1984) and Williams & Arnold (1985) used a 6 cm line scale in the evaluation of ports and the aroma of the coffees, respectively. Marshall & Kirby (1988) used a 12 cm line scale in food texture profiling. Piggott *et al.* (1992) used a continuous line scale anchored at 10% and 90% by the terms "weak" and "strong" for an evaluation of dark rum.

Replication is generally not included in affective sensory evaluation because of selection of a larger, representative sample of the population, *i.e.*,

n≥50 (Larmond, 1976). Nevertheless, a number of FCP studies have used 3 or 4 replicates for the evaluation of chicken flavour, food texture profiling, and in the assessment of the sensory characteristics of cheddar cheese (Lyon, 1987; Marshall & Kirby, 1988; McEwan *et al.*, 1989). Other authors have not used replication within their evaluations of coffee and ports (Williams & Arnold, 1985; Williams & Langron, 1984). FCP has been performed using the same standard facilities ordinarily used in discriminatory or descriptive testing; however, in some studies, the panelists have been told to take the products home and mail the questionnaires back as done in evaluations of wine and cheese (Gains & Thomson, 1990; Guy *et al.*, 1989). FCP has been reported to be a convenient alternative in studies where time and costs are constraints because it utilizes untrained panelists. FCP gives panelists the freedom to express their perception of the product under evaluation and does not require them to use a consensus score card developed by a group, as in QDA. The data collected from FCP needs to be analyzed by General Procrustes Analysis (Gower, 1975).

2.4.3 Generalized Procustes Analysis

Generalized Procrustes Analysis (GPA) is used to analyze data sets wherein separate individuals report on different attributes of the product under evaluation. The panelists normally score R samples for K descriptive terms. The K descriptive terms may vary among the individuals, e.g., if there are two panelists, one panelist may have delineated 14 attributes for the product being

evaluated, whereas the second panelist may have identified only 7 attributes for the same product. The scores of each panelist are then put into a matrix form with attributes in columns and samples in rows. These matrices differ in size because each individual has his/her own number of attributes. The matrices for all panelists are made equal by fitting each individual matrix with zeros if it does not contain the maximum number of attributes. The completed matrices are then subjected to GPA.

GPA goes through various steps of translation, isotropic scaling, and rotation (Dijkesterhuis & Gower, 1992; Lutz, 1994; McEwan & Hallett, 1990; Williams & Arnold, 1985) During translation, there is standardization of the matrices wherein the configuration for each panelist is moved about the origin (0,0). Translation adjusts for panelists who have used different levels of measurement on the scale. It also removes any effect of their scoring an attribute too high or too low. This can happen if two panelists, C1 and C2, score four products E, F, G, H describing one of the attributes, but using different vocabulary, e.g., sweetness (H1) and syrupy (H2). When their configurations are plotted in 2 dimensions, the plot looks initially like the one shown in Figure 2.4.1; but after translation the data configuration will appear as shown in Figure 2.4.2. Figure 2.4.2 shows the scoring difference between panelists C1 and C2 on the scale which was used. According to Oreskovich *et al.* (1991), these scoring differences may reflect an individual response to the perception of different stimuli or a difference in individual sensitivity to a particular attribute.

Figure 2.4.1 Data configuration before being subjected to GPA
(Adapted from McEwan & Hallett, 1990)

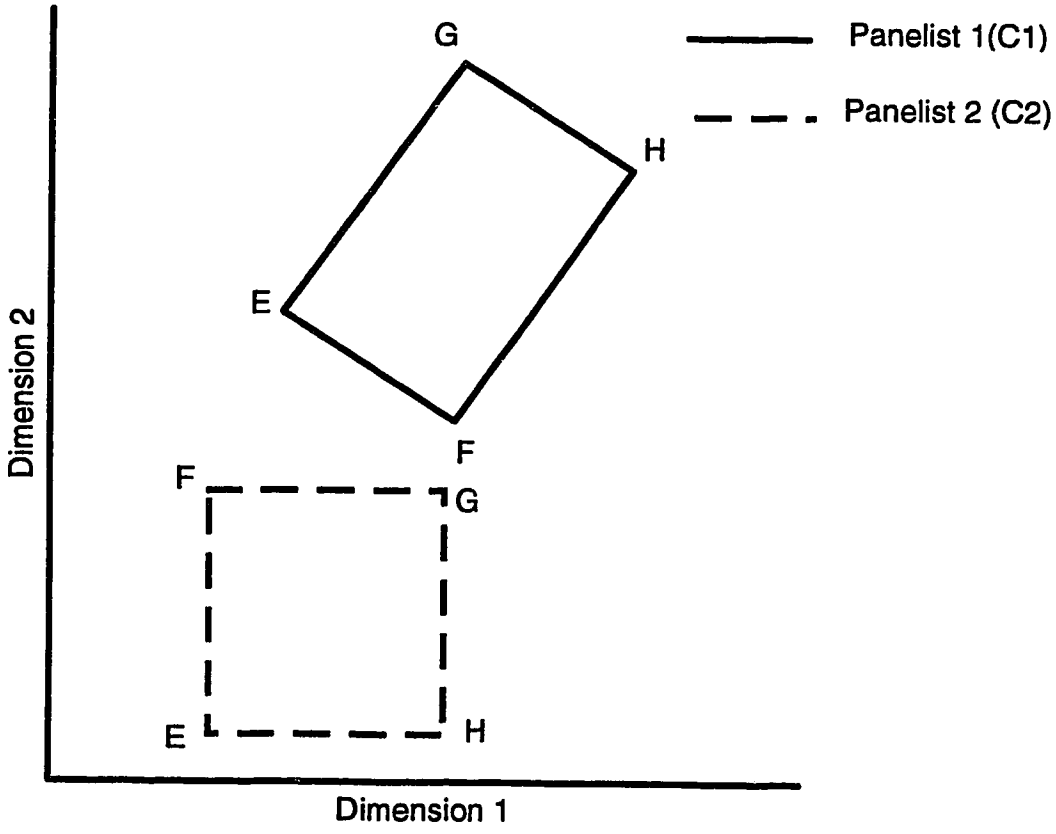


Figure 2.4.2 Translation of matrices in GPA
(Adapted from McEwan & Hallett, 1990)

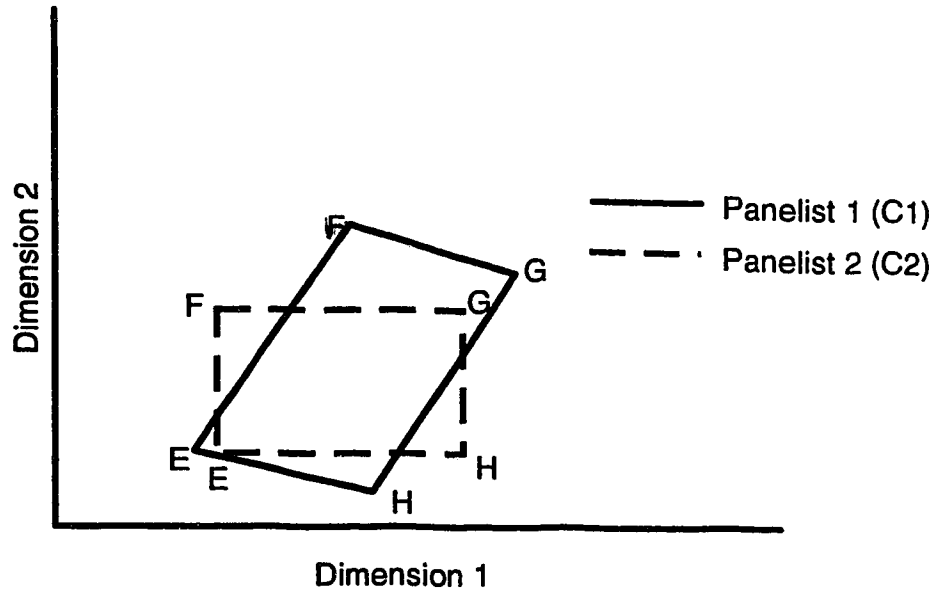
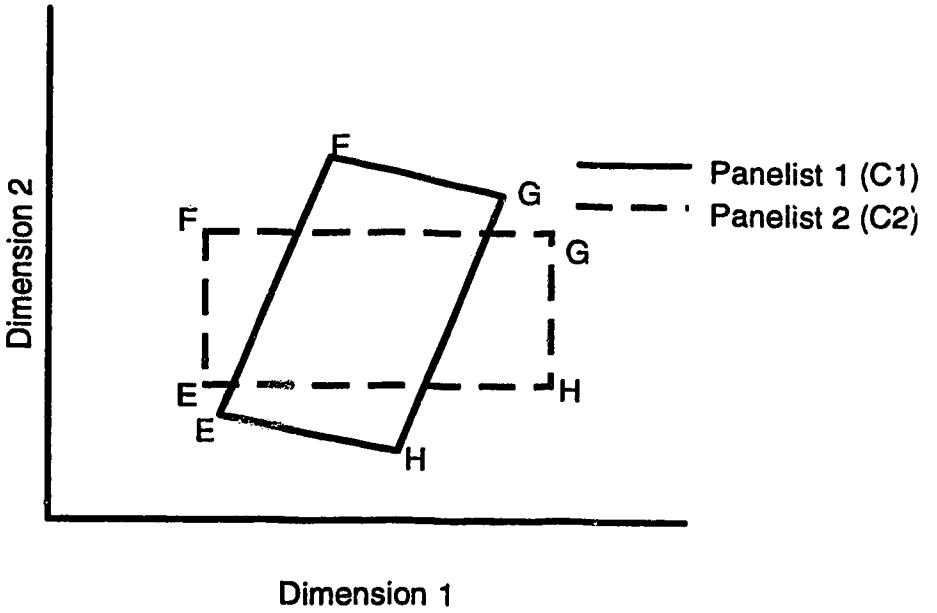


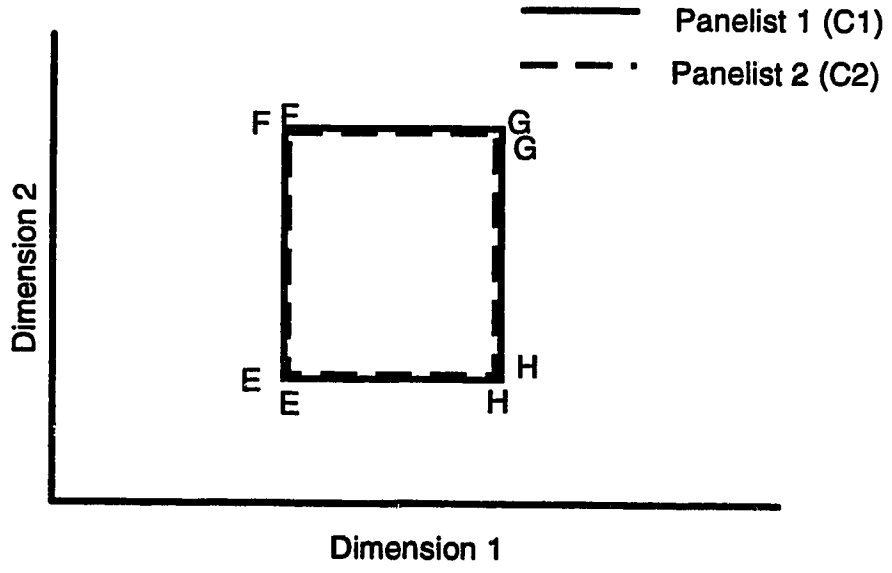
Figure 2.4.3 Stretched and scaled configurations in GPA
(Adapted from McEwan & Hallett, 1990)



An isotropic scaling step then shrinks and stretches all of the panelists' configurations in order to adjust the matrices to the same size and to align them. Figure 2.4.3 shows the same two configurations as before but now their size is almost similar because side EG and FH of Panelist C1's matrix was stretched so that it covers the same area in the two-dimensional plot as Panelist C2's matrix. The scaling and stretching processes adjust for the variation among the panelists due to their different ranges of measurement when they may have used different portions of the scale in their evaluation of the attribute.

The third step in GPA is rotation, a process whereby each configuration is further modified by taking the first matrix as a target matrix and rotating the second panelist's matrix so that alignment occurs. The matrices of the panelists as shown in Figure 2.4.4 are rotated to align with one another. This step adjusts

Figure 2.4.4 Rotated configurations in GPA
(Adapted from McEwan & Hallett, 1990)



for panelists who may have used different attributes to describe the same sample. The configuration shown in Figure 2.4.4 is the one that is used in interpreting each individual's data set. All of these steps of translation, scaling, and rotation of the two configurations do not change the structure of the configurations, but are performed to make interpretation of the data easier.

The GPA program produces Analysis of Variance (ANOVA) results in tabular form. These tables allow assessment of how much effect each of the mathematical steps of translation, rotation and scaling has on the configurations for the sensory panel as a whole. The total variance (V_T) obtained is distributed over the n products, k judges and nk attributes to show the fit of judges and the agreement of judges within the consensus solution which is given by the GPA in a consensus plot. The total variance (V_T) of judge k is represented as Xkij;

$V_T = \Sigma^K\Sigma^n\Sigma^{nk\ (attributes)}Xkij$; the total variance is distributed among the panelists, products, and the principal coordinates and this can be divided into four parts where: $V_T = V_{IN} + V_{OUT} + V_{WITHIN} + V_{PROJECTION}$, with: V_{IN} being the part explained by the first q dimensions (2 in our example) of the consensus space; and V_{OUT} being the part left out as unexplained. This is associated with higher dimensions, e.g., if a two dimensional space explains 79% of the results, 21% is left unexplained. If further dimensions are analyzed, more of the results will be explained based on $V_{IN} = V_{OUT} = V_{CONSENSUS}$; and V_{WITHIN} and $V_{PROJECTION}$ as the residuals coming from different sources. V_{WITHIN} is the part lost in averaging the obtained panelist's space to the consensus space and $V_{PROJECTION}$ is the variance lost in the process of projecting data into the subspaces.

When completed, the ANOVA table produced will show how $V_{CONSENSUS}$ and V_{WITHIN} are distributed among the products. V_{WITHIN} is used in the positioning of the products in the consensus configuration. Therefore, if the value is the same for all products, it means there was an agreement between the judges in the positioning of the products. If the V_{WITHIN} is high compared to the rest, there was disagreement among the judges on the positioning of this particular product in the consensus space. The panelist ANOVA gives out the V_{WITHIN} which is the squared distances between the configuration of a particular panelist and the consensus configuration; this provides the goodness of fit. The value has to be the same if there is a good agreement in the positioning of the product; if the value is higher for one of them, this indicates the lack of fit of that particular panelist.

As well, the ANOVA consists of the dimensions $V_{CONSENSUS}$ and V_{WITHIN}•$V_{CONSENSUS}$, and how much of the analysis is explained by a particular dimension. This indicates where to stop the analysis. If after evaluation of two dimensions, less than 50% of the results are explained, one has to continue the analysis using the third, fourth and higher dimensions until at least the $V_{CONSENSUS}$ is > 50% (Dijkesterhuis & Gower, 1992; Lutz, 1994; McEwan & Hallett, 1990; Williams & Arnold, 1985).

2.5 Consumer acceptance

2.5.1 Factors influencing consumer preference

Consumer acceptance can be defined as the liking or preference for a product. An acceptance test is the one used to show how well products are liked whereas relative acceptance scores only infer preference (Meilgaard *et al.*, 1990). Preference is a consumer's expression of the appeal of one product versus another (Meiselman *et al.*, 1988). Consumers, as individuals, differ in perception, motivation and involvement, as well as in memory, attitudes and lifestyles. Attitude has been reported to be the most difficult aspect of consumer behaviour to understand. Attitudes, once formed, are hard to change and make them an important factor in product development. Other factors that influence a consumer's preference include environmental factors such as social class, household influence, personal influence, situational influence (Meiselman *et al.*, 1988) and culture (Bertino *et al.*, 1983; Ishii *et al.*, 1992, Prescott & Bell, 1995). According to Rozin & Vollmecke (1986), cultural factors are the most powerful determinants of which foods we consume.

2.5.2 Cultural determinants of food acceptance

The world differs in demographics and culture. Demographics can provide some interesting insights into lifestyles and differences among population

segments (e.g., the difference in the usage of many products based on geographical location). Culture may have an impact on an individual's acceptance of a certain food product because it provides a set of norms and shared beliefs that mold and shape a society.

Cross-cultural differences can be caused by inherited perception differences (e.g., sensitivity to bitterness) or preference (e.g., liking of sweetness; dislike of bitterness). Such factors also have an influence on the perception and preference for the product. Dietary experience is another factor that influences the cultural diversity and variability in preference responses to taste, flavour and texture (Prescott & Bell, 1995). Ishii *et al.* (1992) found that Japanese subjects were able to discriminate monosodium glutamate (MSG) and sucrose, whereas North American subjects were unable to discriminate MSG and sucrose. Japanese culture tends to place more interest in the taste of food than does North American culture. Rozin & Rozin (1981) described the tendency of Mexican subjects to describe foods containing no chili as "bland". Those foods which are commonly used by different cultures do not result in differences in identification responses, but the degree of a food's usage will show differences across cultures. Countries that have similar cultures and diets may still show some differences in hedonic preferences as well as for the level of a taste within the food. Hedonic ratings of a particular attribute may also be affected within cultures. Rozin & Schiller (1980) stated that too much of an ingredient can have an effect on the rating of a described attribute. Bertino *et al.* (1983) found that Taiwanese students' ratings were high on the sweet and salty

attributes in food when compared to North Americans, but that North Americans rated the salty attribute lower. Sensitivity of taste to small variations in intensity was not found to differ among cultures. According to Rozin (1995), the sense of taste and smell are similar in adult humans and no difference should be found between cultures. No difference was found in the detection threshold for sweetness, sourness and saltiness among subjects from Nigeria, Korea and the USA (Druz & Baldwin, 1982). In addition, Bertino & Chan (1986) found no difference in the response to sweetness and saltiness between North American and mainland Chinese students living in the USA.

Cross-cultural evaluation of preference for foods is important because it influences cultural expectations for the food and the willingness of the consumer to accept a new product (Pliner & Hobden, 1992). Any possible language barrier is yet another aspect to consider. In descriptive sensory methods, such as FPM and QDA, where proper alignment of attribute concepts within and between panelists is essential, any language problem may be more pronounced. There are certain words which do not have an equivalent synonym in English, e.g., the word *Kusu* in Korean (Prescott & Bell, 1995) and *Umami* in Japanese (Bertino & Chan, 1986). In product development, consumer involvement is a necessity if a successful product is to be marketed. All problems related to cross-cultural differences must be solved, yet little research has been done in the area of language related to acceptance/preference for a food (Cardelo, 1993; Prescott & Bell, 1995).

CHAPTER 3: MATERIALS AND METHODS

3.1 Materials

3.1.1 Whey

Whey used in formulating the working model for this study was purchased from a local cottage cheese processor (Lucerne Dairy, Edmonton), while the remainder of the whey used in the study was manufactured in the Pilot Plant of the Department of Agricultural, Food and Nutritional Science (University of Alberta) from skim milk purchased from another local dairy (DairyWorld, Edmonton). Two types of whey were used in this project. "Heated whey" (HW) was prepared by heating 10 L of skim milk to 100°C for 10 minutes and then cooling to 50°C, while the "control whey" (CW) was prepared by raising the temperature of 10 L of skim milk to 50°C; in both cases, sufficient food grade lactic acid (Fisher Scientific Co.) was added to lower the pH to 4.6-4.7 (Patocka & Jelen, 1987). The whey was then clarified by centrifugation at 10,000 rpm (LAPX 202, Alfa-Laval, Tumba, Sweden) to remove casein fines (Patocka & Jelen, 1989).

3.1.2 Bananas

Fresh, ripe, golden yellow bananas *(Musa* spp.*)* with brown flecks, maturity stage 7 (Mariott & Lancaster, 1983) were purchased, as needed, from a local supermarket (Canada Safeway). The bananas were washed, peeled, and blended in a commercial blender (Model 31BL92, Dynamics Corp., Waring Division, New Hartford, CT 06057, USA) for 1 minute to obtain a homogeneous banana puree. This banana puree, prepared when required, was then used in all combinations with whey in the production of the whey-banana beverages.

3.1.3 Reagents

All laboratory grade reagents required for the preparation of whey, the proximate analyses, and the sugar and mineral analyses, *i.e.*, lactic acid, hydrochloric acid, acetonitrile, etc. were purchased from Fisher Scientific Co. (Fair Lawn, NJ 07410, USA).

3.1.4 Stabilizers

Keltrol RD and Keltrol T, food grade xanthan gum products, were obtained from the Kelco Company (San Diego, CA 92123, USA). These products were in dried form.

3.2 Processing methods

3.2.1 Heating processes

To investigate the effect of heat-sensitive whey proteins on sedimentation in whey-banana beverages, two types of whey, CW and HW, were used. To produce the HW, 10 L of skim milk was heated to 100°C and then cooled to 50°C in an open kettle (Model TD/2-40QT, Dover Corp., Groen Division, Elk Grove Village, IL, USA.). The total heating time was approximately 15 minutes (holding at the boiling point for 5 minutes). This milk was used in the production of HW as described in 3.1.1. To produce the CW, 10 L of skim milk was heated to 50°C in the same open kettle as for HW; total heating time was approximately 15 minutes. This milk was used in the production of CW as described in 3.1.1.

In order to control enzymatic browning reactions in the whey-banana beverages, the banana puree was heated, stirring continuously, in a beaker to 80°C and held for 2 minutes in a 100°C water bath (Koffi *et al.*, 1991). After heating, the puree was cooled quickly in an ice bath to minimize the Maillard browning reaction. An alternative method of browning control was also investigated by heating the HW to boiling and mixing the boiling HW with the unheated banana puree while stirring on a hot plate to bring the temperature to 80°C. The mixture was then held for 2 minutes and cooled quickly in an ice bath.

3.2.2 Production of whey-banana beverages

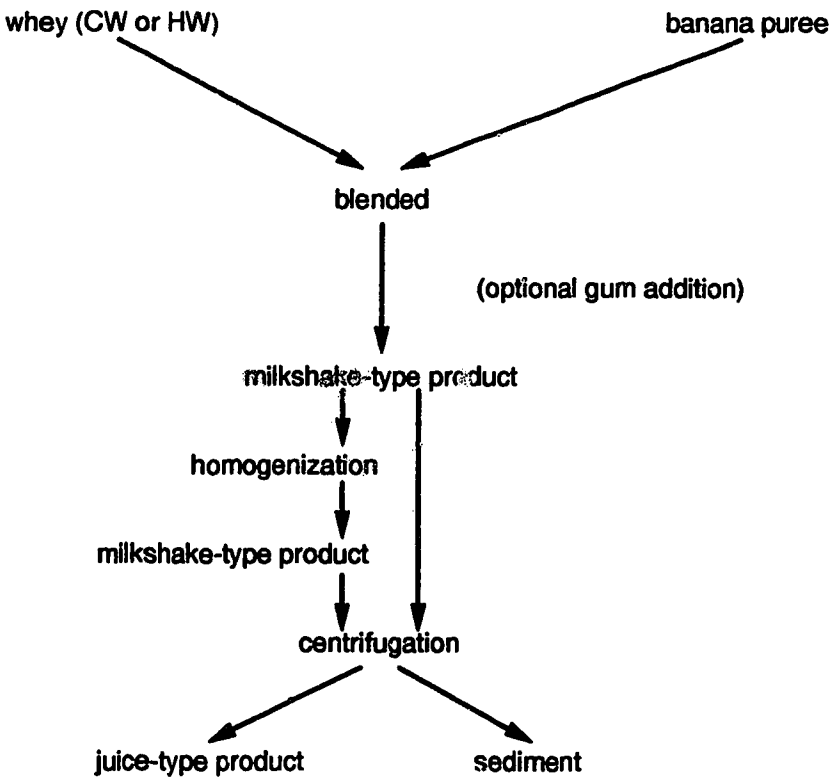
In the preliminary studies, a blend of 2 parts banana to 3 parts whey was found to be the most acceptable formula. All whey-banana beverages used in the main study were prepared in the laboratory using the preferred formula of two parts of banana puree mixed with three parts of either HW or CW. The mixture of whey and banana puree at room temperature was blended in a blender (Model 31BL92, Dynamics Corp., Waring Division, New Hartford, CT 06057, USA) for 2 minutes. This process resulted in a thick, milkshake-type product. Half of each "shake" was centrifuged at about 800 x *g* for 10 minutes as described in 3.2.4. The supernatant was decanted to obtain juice-type products and the sediment was harvested. Figure 3.2.1 shows the procedure used to make different types of whey-banana beverages. Each batch of beverages was made in two replicates.

3.2.3 Homogenization

After blending, the whey-banana milkshake-type beverages showed immediate sedimentation. Homogenization was, therefore, studied as a means to control the sedimentation and also in an attempt to obtain a smooth milkshake-type product. The products were homogenized at 25°C in a single stage Westinghouse WK 16 dairy-type piston homogenizer (l5m8BA Manton-Gaulin

Mfg. Co., Everett, MA, USA) at a pressure of 2.75 x 10^2 N/m^2 (Figure 3.2.1).

Figure 3.2.1 Generalized flow diagram of whey-banana beverage preparation



3.2.4 Centrifugation

In order to obtain juice-type products, clear and free of sediments, the whey-banana "shakes" were centrifuged using a JA 14 rotor in a Beckman centrifuge, Model J2-21 (Beckman Instruments, Inc., Palo Alto, CA, USA) at about 800 x *g* for 10 minutes. The supernatant was decanted as a juice-type product and the sediment was harvested for further analysis.

3.2.5 Stabilization of whey-banana shakes

The prototype milkshake products were produced following the procedures given in 3.2.2. The addition of stabilizers (Keltrol RD and Keltrol T) was at three levels: 0.1%, 0.2%, and 0.3% (w/w) to achieve stabilization. The mixtures were blended in a blender (Model 31BL92, Dynamics Corp., Waring Division, New Hartford, CT 06057, USA) and one half of the resulting product was homogenized using a dairy-type piston homogenizer (Westinghouse WK16 I5m8BA, Manton-Gaulin Mfg. Co., Everett, MA, USA) at a pressure of 2.75×10^2 N/m^2. The shakes were observed for visual stability.

3.3 Determination of physical properties of the whey-banana beverages

3.3.1 Viscosity measurements

The apparent viscosities of both types of whey-banana beverages were measured according to Schimdt & Smith (1989) using a Haake Rotovisco Viscometer (Rv3) which was connected to a sensor (Gebrüder Haake, Berlin, Germany) and recorded by using an IBM compatible computer. The temperature of the solution was maintained at 20°C using a Thermomix 1480 circulating water bath (Gebrüder Haake, Berlin, Germany). The shear rate was kept

constant with a fixed rpm setting of 64. Apparent viscosity was recorded at 1 minute intervals for a period of 10 minutes.

3.3.2 Turbidity measurements

Turbidities of whey-banana juices were measured using a Spectronic 21 spectrophotometer (Bausch & Lomb Inc., Rochester, NY, USA) at a wavelength of 600 nm. Absorbance readings of the samples were measured at room temperature and compared with each other.

3.3.3 Visual stability of whey-banana "stabilized" shakes

A visual examination of the clear whey separation was used as the principal stability test for the whey-banana shake. This examination was performed by filling 10 mL graduated tubes with sample, letting them stand in a 4°C cooler, and allowing separation by gravity. The samples were inspected visually at zero, 24, and 48 hours and the level of the clear whey separated at the bottom of the tube was recorded by subtracting from 10 mL to obtain the volume of the separated whey.

3.3.4 Colour measurements

The colour of the whey-banana juice beverage was quantified using a colour meter (Model D25 Optical Head,. Hunter Associates Lab, Inc., Fairfax, VI, USA) by placing 10 mL of each sample in a 100 x 15 mm standard petri dish (Fisher Scientific Co.). A white tile was used as a standard. For each sample, the colour parameters L, a, and b were determined at zero, 24 and 48 hours. Samples were held at 4°C until the measurement was carried out. Samples were measured in triplicate by rotating each petri dish by 45°.

3.4 Chemical analyses on the whey-banana beverages

3.4.1 Proximate analysis

Two replicates of all samples were used for each analysis. Determination of total solids, fat, and ash was carried out in duplicate according to Association of Official Analytical Chemists (AOAC) procedures (1990).

The protein content of the samples was analyzed using a microprocessor based software controlled instrument (LECO MODEl FP428, Nitrogen determinator system, 601-700-900, Leco Corp., St. Joseph, MI 49085-2396, USA). A tin capsule containing 250 mg of a sample was dropped into a hot furnace at 850°C and flushed with pure oxygen for rapid combustion to produce

CO_2, H_2O, NO_2 and N_2. The mixture was then measured by thermal conductivity to obtain its nitrogen content which was then converted to the percentage protein using a factor of 6.25.

The carbohydrate content was determined using a method (CaRl.00, O.S. Longman routine method, Alberta Agriculture, Food and Rural Development) whereby the samples of whey-banana shake, whey-banana juice, and whey-banana sediment were analyzed, using acid hydrolysis to break down the starch to simple sugars and then analyzed for glucose. The glucose content was obtained using the Munson Walker method (AOAC, 1990). The fructose and sucrose lost during acid hydrolysis was corrected for by adding 0.2% sucrose and 0.4% fructose. The amount of starch was calculated as the difference between the carbohydrate content and the total sugars present. Acid detergent fibre was determined, and in order to obtain the roughage fibre content, the result was multiplied by a factor of 0.6 (O.S. Longman routine method, Alberta Agriculture, Food and Rural Development).

3.4.2 Mineral analysis

The mineral content of the homogenized shakes and juices were determined using a JY70 Plus (I.S.A. Jobin Yvon, Longjumeau Cedex, France). This analysis was carried out after 20 g of sample was digested by a mixture of 30 mL nitric acid in 70 mL double distilled, deionized water on a 0.5 setting in a digestor (Model 20-1015, Tecator Co., Hoganas, Sweden) and filtered.

3.4.3 Sugar analysis

Sucrose, glucose, lactose and fructose levels were determined on the various whey-banana beverages and sediments by diluting 10 g of a sample in a volumetric flask to 100 mL, filtering it once through folded fast flow filter paper, and then again through 0.4 μ millipore filter. Appropriate aliquots of this filtrate was then injected into an HPLC (Model 221, Scientific Systems Inc., State College, PA 16801, USA) using 16% acetonitrile in H_2O as the mobile phase. The sugar levels were detected by the refractometer (410 Differential Refractometer, Waters Co., Milford, MA 01757, USA) and recorded by a ChromotoPac (C-R3A, Shimadzu Corp., Analytical Instrument Division, Kyoto, Japan). The temperature of the carbohydrate column was 30°C.

3.5 Sensory evaluation

3.5.1 Evaluation of whey-banana beverages

A preliminary sensory test using 8 untrained African students was carried out at the beginning of the project to decide the most appropriate whey to banana formulation. In an informal laboratory setting, ranking of four products containing different whey to banana ratios was used.

A second, properly controlled, sensory preference test was carried out to determine which type of the whey-banana beverages was most suitable for

further investigation. The evaluation of preference was performed using a 9-point hedonic scale (Meilgaard *et al.*, 1991).

A total of 22 panelists were recruited, based on availability and

Figure 3.5.1 Sensory score card for evaluation of preference of whey-banana beverages

EVALUATION OF WHEY-BANANA BEVERAGES

Name: ______________________ Date: ________
Product: ______________________
Instructions: Taste these samples and check below how much you like or dislike each.

Sample: ________

( )	( )	( )	( )	( )	( )	( )	( )	( )
like extremely	like very much	like moderately	like slightly	neither like nor dislike	dislike slightly	dislike moderately	dislike very much	dislike extremely

Sample: ________

( )	( )	( )	( )	( )	( )	( )	( )	( )
like extremely	like very much	like moderately	like slightly	neither like nor dislike	dislike slightly	dislike moderately	dislike very much	dislike extremely

Sample: ________

( )	( )	( )	( )	( )	( )	( )	( )	( )
like extremely	like very much	like moderately	like slightly	neither like nor dislike	dislike slightly	dislike moderately	dislike very much	dislike extremely

Sample: ________

( )	( )	( )	( )	( )	( )	( )	( )	( )
like extremely	like very much	like moderately	like slightly	neither like nor dislike	dislike slightly	dislike moderately	dislike very much	dislike extremely

experience. The sensory panel consisted of graduate students and staff of the Department of Agricultural, Food and Nutritional Science (University of Alberta). All 22 panelists evaluated the shake-type products, while only 18 of them evaluated the juice products. The panel did not receive training, the only instruction given was how to use the score card at the beginning of the session.

This consumer-type panel evaluated four samples on the same day. In each session either four juices or four shakes were evaluated. Evaluation of each type of beverage was replicated once. The evaluation was conducted in a sensory room with each panelist in an individual booth and no communication occurred between the panelists. Each panelist was presented with 30 mL of each sample coded with 3-digit random numbers and presented randomly and a score card (Figure 3.5.1). The samples were contained in a covered transparent plastic glass. Panelists were instructed to mark how much they liked or disliked the beverages using the provided score card. The data for each set of beverages were subjected to one-way ANOVA

3.5.2 Free Choice Profiling

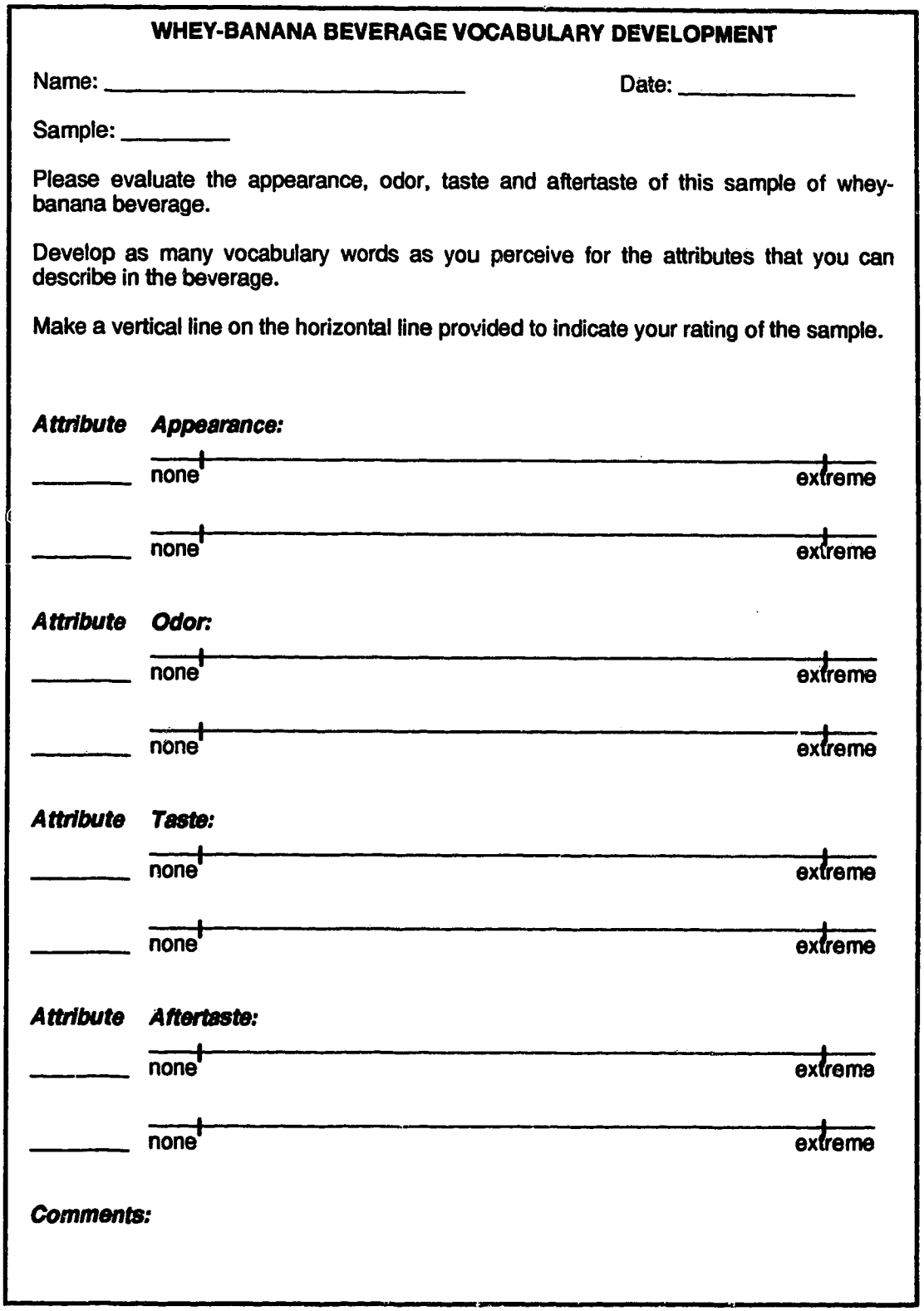
The objective of FCP was to carry out further sensory evaluation of the whey-banana juice-type beverages produced, using an untrained consumer panel to represent the naïve consumers of the product's target market. Four types of juices were evaluated. The samples evaluated were prepared on the same day of the evaluation according to procedures given in 3.2.2. The FCP

consumer panel consisted of two major groups of untrained panelists (2 x 12 = 24). One group consisted of Canadian panelists while the second one consisted of African panelists. Among the panelists, 15 were females and 9 were males, their age ranging from 23-50, all of whom were either students or staff at the University of Alberta. Among the panelists, 13 were inexperienced, performing sensory evaluation for the first time; however, all of them were doing FCP for the first time.

There were four sensory evaluation sessions. The first two were used for the vocabulary development, whereby each panelist developed an individual vocabulary list to describe the perceived attributes of the samples. In the first session of vocabulary development, the judges were introduced to the subject and shown a few generalized examples on how to come up with vocabularies referring to hypothetical FCP experiments. The only instruction given to the panelists was to taste the samples in the order indicated and to evaluate one sample at a time while trying to perceive as many attributes as could be perceived by the individuals. The categories of appearance, odor, taste, and aftertaste were to be evaluated separately on the score card (Figure 3.5.2). The attributes perceived were to be written down on the vocabulary development sheet given out which had 15 cm lines drawn under each of the four categories. The lines were anchored at 1.5 cm on each end by the descriptors "none" and "extreme".

In the first session, the panelists were given two coded samples (beverages 3 and 4) selected from the four whey-banana juice-type beverages to

Figure 3.5.2 Vocabulary development sheet for whey-banana beverages (not to scale)



WHEY-BANANA BEVERAGE VOCABULARY DEVELOPMENT

Name: _____ Date: _____

Sample: _____

Please evaluate the appearance, odor, taste and aftertaste of this sample of whey-banana beverage.

Develop as many vocabulary words as you perceive for the attributes that you can describe in the beverage.

Make a vertical line on the horizontal line provided to indicate your rating of the sample.

Attribute Appearance:

_____ none ——— extreme

_____ none ——— extreme

Attribute Odor:

_____ none ——— extreme

_____ none ——— extreme

Attribute Taste:

_____ none ——— extreme

_____ none ——— extreme

Attribute Aftertaste:

_____ none ——— extreme

_____ none ——— extreme

Comments:

assist them in describing the attributes. Each panelist was sequentially given 30 mL of each sample in a transparent plastic glass on a tray along with a separate vocabulary development sheet. He/she was asked to evaluate the product on their own. The samples were presented randomly, one at a time, in coded plastic glasses covered with aluminum foil, accompanied by a glass of double distilled, deionized water for rinsing and a score card. The evaluated beverage and its respective score card was removed from the panelist before another beverage was presented.

In the second session, the panelists were given 30 mL each of the remaining 2 beverages (beverages 1 and 2) and asked to sample them again to redefine their vocabulary list, adding the attributes they had left out and eliminating any they thought did not really exist. The panelists were instructed to replace any vocabulary that was not unidirectional or descriptive of the beverage (Lutz, 1994; Oreskovich *et al.*, 1991).

After the first two sessions, individualized score cards were prepared for each of the 24 panelists which reflected the number of individual attributes identified by each panelist. Each questionnaire had a few extra lines in each category to allow panelists to add any new attribute which might be perceived while doing the actual evaluation of the beverages. At the end of each score sheet there was one 15 cm line provided for evaluation of "acceptability". This line was hedonic in nature and anchored with "like" and "dislike" at either end, and the panelists were required to evaluate their preference of the beverage.

The sensory evaluation of the beverages was carried out on the two

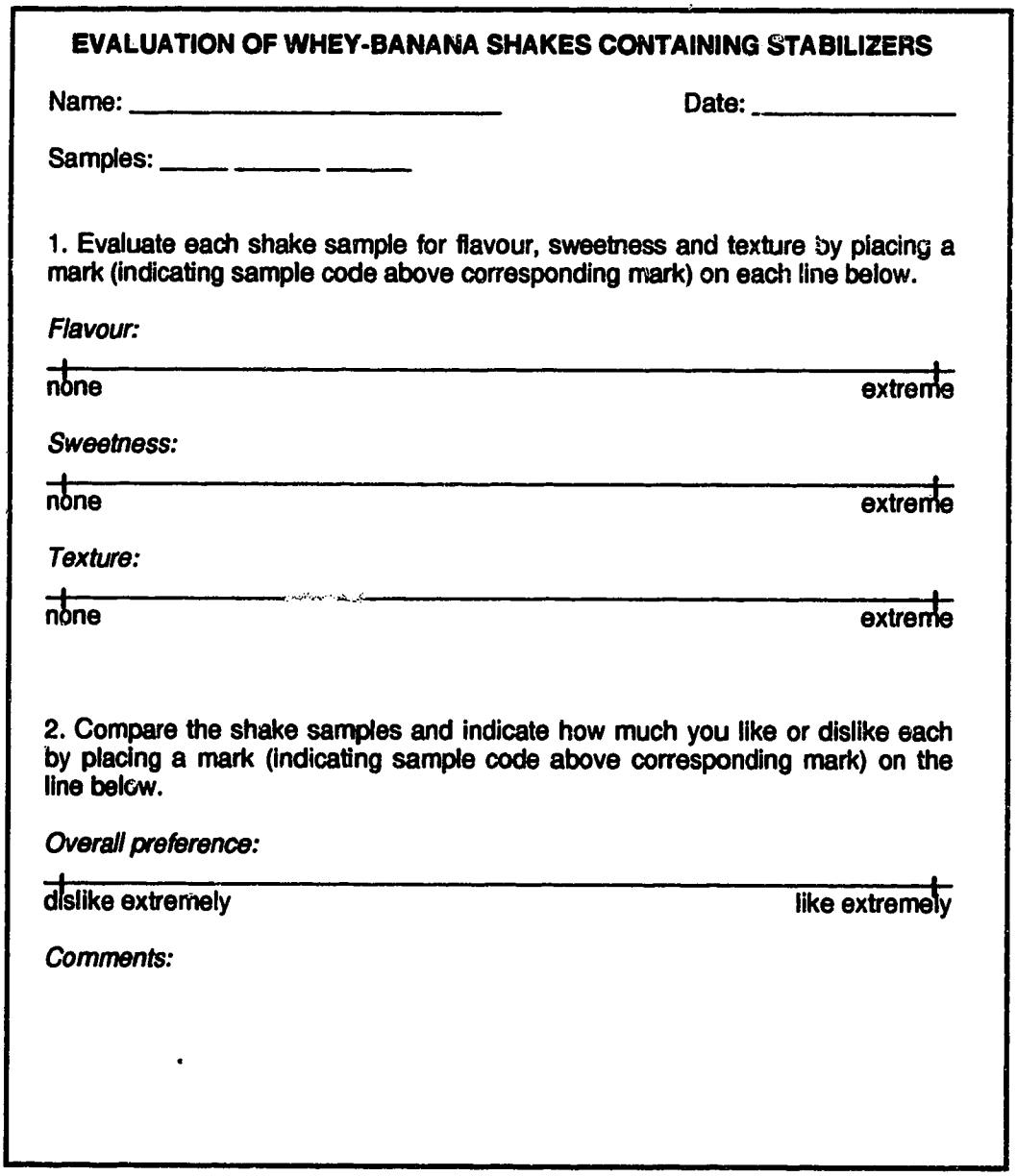
replicates using the two remaining FCP sessions. In the first session, the panelists were given four samples, one at a time, in a transparent plastic glass covered with aluminum foil on a tray. All samples were coded with three digit random numbers and presented in random order. The panelists were also supplied with double distilled, deionized rinsing water in a glass, an expectoration glass, and an individual score card for the evaluation. All samples were evaluated individually. The second replicate of whey-banana juices was performed two days later with fresh samples made on that day. The FCP study took two weeks. Numerical values were given to the ratings on the various attributes by measuring the distance of the panelists' marks from the left end of the line to the nearest 0.1 cm.

3.5.3 Evaluation of the whey-banana shakes made with stabilizers

The objective of this experiment was to determine the effect of the stabilizers on the perceived quality and preference of whey-banana shakes made as outlined in 3.2. The number of panelists participating in the evaluation of these shakes was 22. Among them, 15 were exchange students attending the University of Alberta through the International Association for the Exchange of Students for Tecnical Experience (IAESTE), while the remainder were either graduate students or staff in the Department of Agricultural, Food and Nutritional Science. The sensory evaluation was performed in a manner identical to that described in 3.5.1 except that a different score card was used (Figure 3.5.3).

The shakes were prepared on the same day as the evaluation according to 3.2.2 and 3.2.5. The panel evaluated the beverages for flavour, sweetness, texture, and overall preference. Three products were evaluated (two with stabilizer, one control) in a single session.

Figure 3.5.3 Sensory score card for evaluation of stabilized whey-banana shakes (not to scale)



EVALUATION OF WHEY-BANANA SHAKES CONTAINING STABILIZERS

Name: _____ Date: _____

Samples: _____ _____ _____

1. Evaluate each shake sample for flavour, sweetness and texture by placing a mark (indicating sample code above corresponding mark) on each line below.

Flavour:

none — extreme

Sweetness:

none — extreme

Texture:

none — extreme

2. Compare the shake samples and indicate how much you like or dislike each by placing a mark (indicating sample code above corresponding mark) on the line below.

Overall preference:

dislike extremely — like extremely

Comments:

3.6 Statistical data analysis

ANOVA, t test and descriptive analysis were used in analyzing data obtained from turbidity, viscosity, sedimentation and visual stability. The differences in measurements of the colour of the beverages and acceptability of the beverages were analyzed using General Linear Model Procedure and Students-Newman-Keuls Test in a nested split plot design using SAS programme.

The data matrices of (beverages x attributes) derived from FCP of each panelist were made and in order for all matrices to conform with the maximum number of attributes they were filled with dummies. These matrices were then input into the APL Program and analyzed by using GPA (Procrustes, PC V.2.0, Computer Software Oliemans Punter and Partners, Inc., Utrecht, Netherlands; Gower, 1975).

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Working formulation

As a starting point, it was necessary to find a whey-banana shake working formulation which contained an appropriate mixture of whey and banana. Whey-banana shakes were prepared using four different ratios of whey to banana puree; 5:2; 3:2; 3:1 and 4:1. Each of these mixtures was blended in a blender for 2 minutes, producing a milkshake-type product. In order to select the right formula for the right target consumer group, a simple, preliminary sensory evaluation test was carried out using a ranking method and an untrained panel composed of 8 African students attending University of Alberta. This study was done with the objective of choosing from the four varieties of milkshake-type product the most suitable formula to be used for further study. The evaluation indicated that the products were significantly different at $p \leq 0.05$. The panel preferred shakes in the following order of formulation 3:2, 5:2, 3:1, and 4:1 (from most acceptable to least acceptable, whey to banana) (Table 4.1.1). From these results, the formula 3:2 (w/w) of whey to banana was chosen as the working formulation.

Table 4.1.1 Preliminary sensory evaluation for a working formulation

Products[1] / *Panelist*	A (5:2)	B (3:2)	C (3:1)	D (4:1)
1	3	1	2	4
2	2	1	3	4
3	3	1	4	2
4	1	2	3	4
5	2	1	4	4
6	1	2	4	3
7	2	1	2	3
8	2	1	3	4
Rank sum[2]	$14^{c,d}$	10^{d}	24^{b}	$29^{a,b}$

[1] Product formula ratio, whey to banana puree.
[2, a, b, c, d] A rank sum followed by the same letter is not significantly different ($p \geq 0.05$).

4.2 Control of enzymatic browning

Bananas contain the enzyme polyphenoloxidase (PPO) which is responsible for enzymatic browning reactions. The prototype beverages as described in 3.2.2 were found to brown easily. Two methods were investigated for inactivating PPO; one was that of heating the banana puree on a hotplate (HP) and the other was by heating the banana puree with the addition of boiling whey (HE) (3.2.1). Juice colour was used as a measurement of the inactivation of PPO; shake-type products were not measured for colour. Both methods

showed the colour of the whey banana juices to improve significantly ($p \leq 0.05$) with heat treatment. The Hunter colour difference meter measurements showed that, compared to the control juices E and F, the L-value increased for juice samples A, B, C, D (*i.e.*, Figure 4.2.1, the higher the L-value, the lighter the juice). The b-value decreased indicating increasing yellow colour (*i.e.*, Figure 4.2.2, the lower the b-value, the higher the yellowness). Also, the a-value, measuring greenness, decreased (Figure 4.2.3, the lower the a-value, the lower the greenness). When the two heat treatments were compared, there was no statistical difference ($p \geq 0.05$) between juices A and B made by HP and juices C and D by HE methods for both the L-value and b-value; but there was a significant difference ($p \leq 0.05$) in the a-value for the HE method as exhibited by the decrease in the a-value compared to that found for the HP method.

Table 4.2.1 Whey-banana juices used in control of browning investigation

Product	*Processes involved in juice manufacture*
A	Heated puree, not homogenized
B	Heated puree, homogenized
C	Unheated puree and boiling whey, not homogenized
D	Unheated puree and boiling whey, homogenized
E	Unheated puree, not homogenized (control)
F	Unheated puree, homogenized (control)

Figure 4.2.1 Colour measurement of whey-banana juice (L-value) in control of enzymatic browning with respect to holding time (for key see Table 4.2.1)

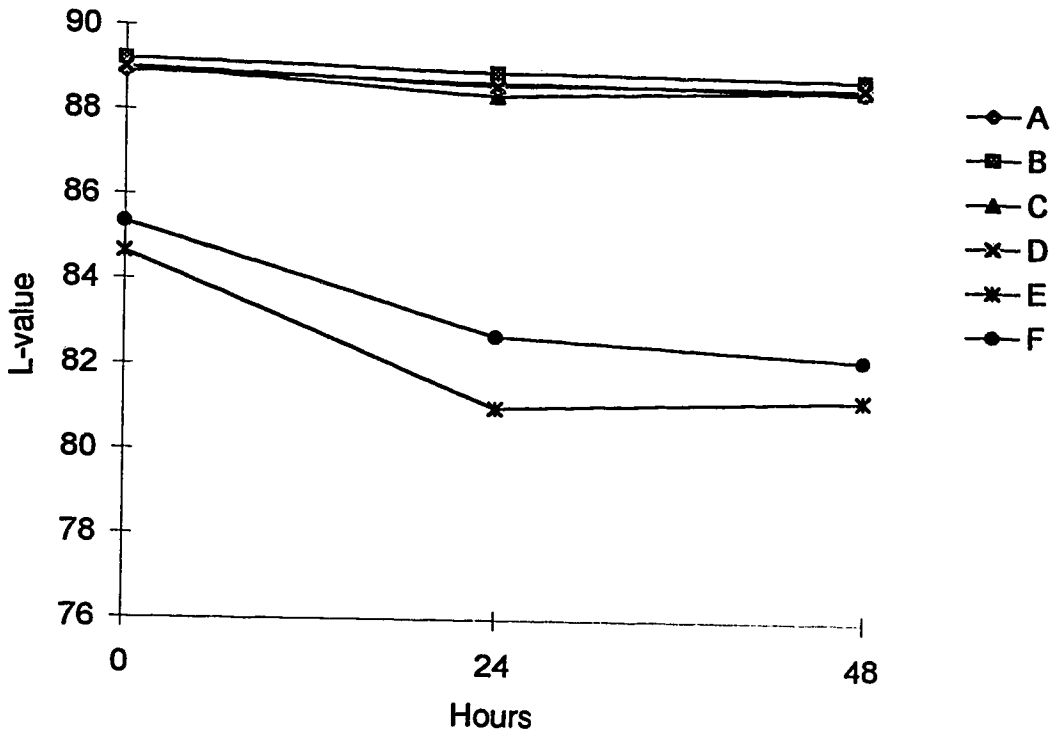


Figure 4.2.2 Colour measurement of whey-banana juice (b-value) in control of enzymatic browning with respect to holding time (for key see Table 4.2.1)

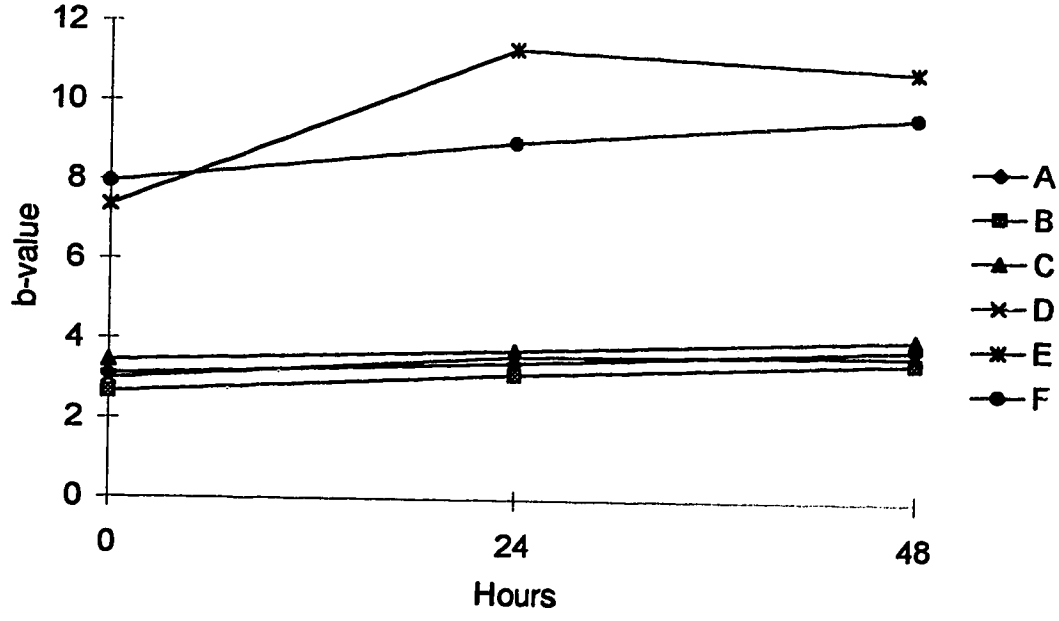
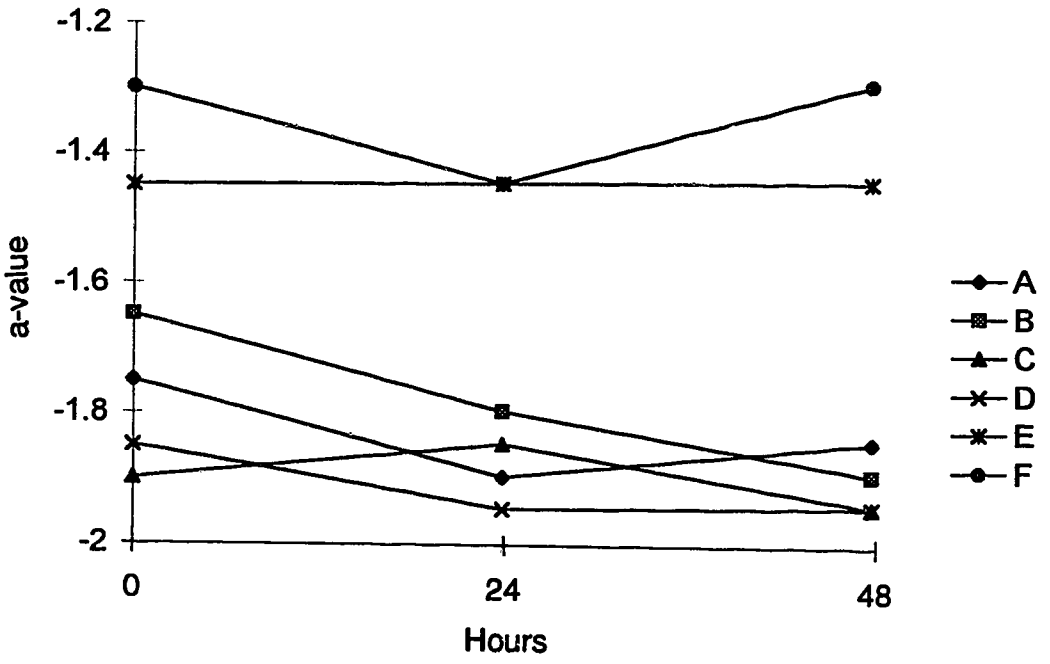


Figure 4.2.3 Colour measurement of whey-banana juice (a-value) in control of enzymatic browning with respect to holding time (for key see Table 4.2.1)



4.3 Effect of heat treatment of skim milk on beverage characteristics

The objective of this part was to find out if heating of the skim milk to the boiling point prior to the preparation of the whey had an effect on the characteristics of the whey-banana beverages. One of the major reasons for sedimentation in fruit containing whey beverages is thought to be whey proteins interacting with the pectin component. Therefore, it was thought that by the removal of some whey proteins, sedimentation in the beverages could be reduced. The practice of heating milk directly in Tanzania was another reason to investigate the effect of heating the skim milk. The characteristics investigated were: viscosity for both the juice and shake-type products, as well as turbidity

and colour (L-value) for the juice type products.

All of the whey-banana shakes were found to be pseudoplastic, while the whey-banana juices were approximately Newtonian. The results in Table 4.3.1 show that the heating of skim milk decreased the apparent viscosity of both shake and juice-type products. The viscosity of beverages made from CW was higher when compared to that of HW products. This can be explained by possible interactions between whey proteins and banana pectins, tannins or possibly starches. These results are in agreement with Osman & Cummisford (1959) and Osman (1967) who found that starch paste in milk showed higher viscosity values than those for starch in water. As HW lost much of its whey protein by denaturation, coagulation and then removal with caseins, the remaining milk components in solution were lactose, non-heat coagulable whey protein residues, and mineral salts. The reduction of whey proteins in the HW products possibly contributed to different values of viscosity.

Table 4.3.1 Effect of heating of skim milk on the viscosity, turbidity, and colour of whey-banana beverages

Treatment	*Viscosity ($x10^{-3}$)mPa*		*Turbidity (abs[1])*	*Colour (L-value)*
Product	Shake	Juice	Juice	Juice
Unheated[2]	35.90[a]	6.48[a]	0.95[a]	85.25[a]
Heated[3]	21.87[b]	4.98[b]	0.28[b]	84.35[b]

[1] Absorbance reading at 600nm.
[2] Beverages produced from whey made from unheated skim milk.
[3] Beverages produced from whey made from heated skim milk.
[a,b] Mean values in a column followed by the same letter are not significantly different ($p \geq 0.05$).

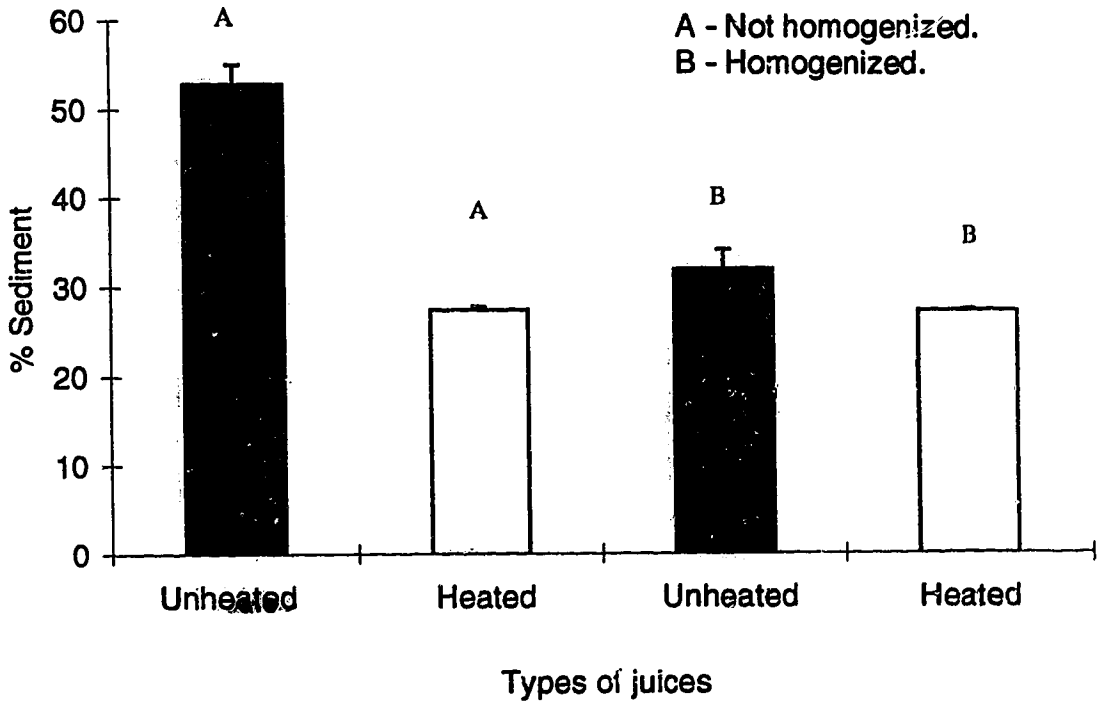
One of the main reasons that may contribute to the failure of whey-fruit beverages in the marketplace is the cloudiness, sediment formation and turbidity in these products (Jelen, 1992). The effect of heating the skim milk before preparation of the whey to be used on these characteristics was investigated. The turbidity results indicated that juices made from HW were less turbid as indicated by the lower absorbance values at 600nm, compared to those made from CW. This is in agreement with Devkota (1991) who observed the same phenomena – when whey and juice were mixed together, turbidity occurred. This work showed that undenatured whey proteins react with pectin forming turbidity and sediment, with or without heating. Other researchers (Hill & Zadow, 1978, 1974) reported the possible interaction of a polysaccharide like pectin with whey protein.

The colour of the juices was compared by measuring the L-values. The lightness of the juices was shown to increase with the HW juices (higher L-value). Those juices made from CW had lower L-values (Table 4.3.1). With CW, there may have been a possible interaction between the whey proteins and banana tannins and pectins to form complex components which brought on a haze in the juice.

4.4 Sedimentation

The shakes separated immediately when left to stand. In the production of juices, a substantial amount of sediment was harvested as shown in Figure 4.4.1. Heating of skim milk prior to the preparation of the whey reduced sedimentation significantly ($p \leq 0.05$) from 52.8% in CW beverages to 27.3% in HW beverages. This can also be explained by a possible interaction between the whey proteins and the banana pectins and tannins, which produces bulky, highly hydrated sediment.

Figure 4.4.1 Sediment (% w/w) harvested in production of whey-banana beverages



4.5 Effect of homogenization

The objective of using the homogenization process was to reduce the sedimentation. One of the main reasons for sedimentation is the size of the particle (Jinescu, 1974). When the homogenization process was applied, the amount of sediment harvested from both HW and CW products was reduced (Figure 4.4.1). CW products showed greater effect in reduction of sediment than HW products. Possibly, under high pressure, the flocs of whey protein-pectin aggregates are ruptured, thereby releasing entrapped fluid and decreasing the volume of the sediment.

Homogenizing the shake-type products reduced significantly ($p \leq 0.05$) the viscosity of both HW and CW banana shake and juice beverages as shown in Figures 4.5.1 and 4.5.2. These results are in broad agreement with the observations of Holmes & Rha (1978) who showed that there was a decrease in the viscosity of suspension after homogenization in their studies of cranberry cell wall material. Crandall & Davis (1988) also reported that homogenization was able to reduce the viscosity of an orange juice concentrate. One of the factors which can affect the apparent viscosity of a whey-banana shake-type product is possibly the structure of the insoluble particles, the volume, size, shape, number and interactions of particles which are basic factors affecting the rheological properties of a system (Rha, 1978). The aggregates formed could be deformed as a result of homogenization, resulting in a decrease in viscosity.

The turbidity values of the juices were also reduced significantly ($p \leq 0.05$);

the absorbance reading decreased from 0.95 to 0.75 for the unheated juice and from 0.28 to 0.05 for heated ones (Figure 4.5.3) indicating the heating skim milk prior to preparing the whey and then carrying out homogenization produced less turbid beverages. Homogenization under high pressure is believed to have broken up the suspended particles into smaller sized ones, thus reducing turbidity.

Colour lightness of the juices also improved as a result of homogenization of the shake-type products, giving higher L-values for both heated and unheated whey-banana juices as shown in Figure 4.5.4.

Figure 4.5.1 Effect of homogenization on viscosity of the whey-banana shakes

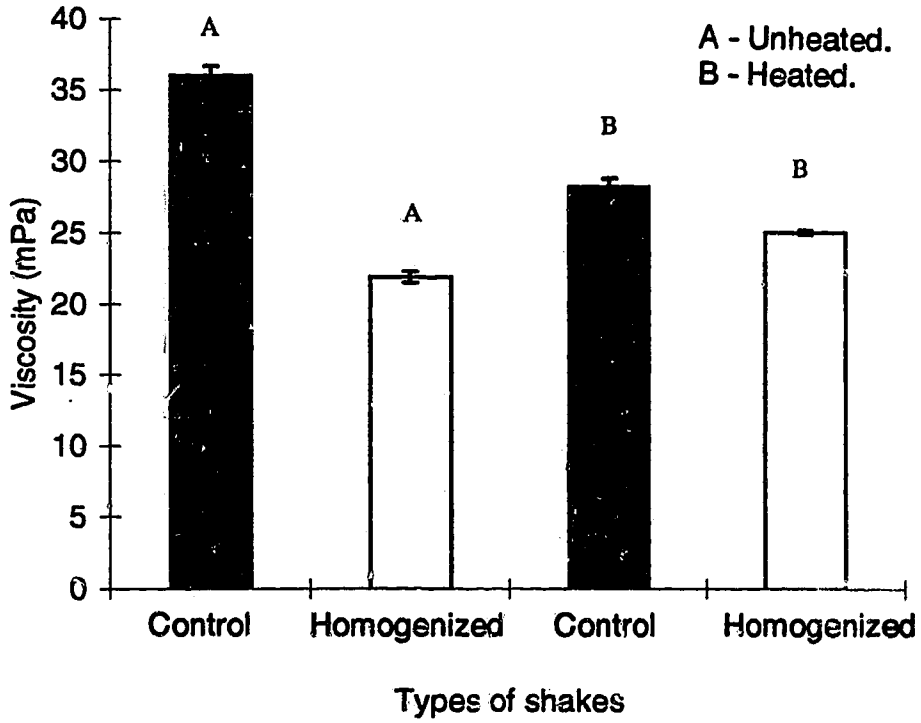


Figure 4.5.2 Effect of homogenization on viscosity of the whey-banana juices

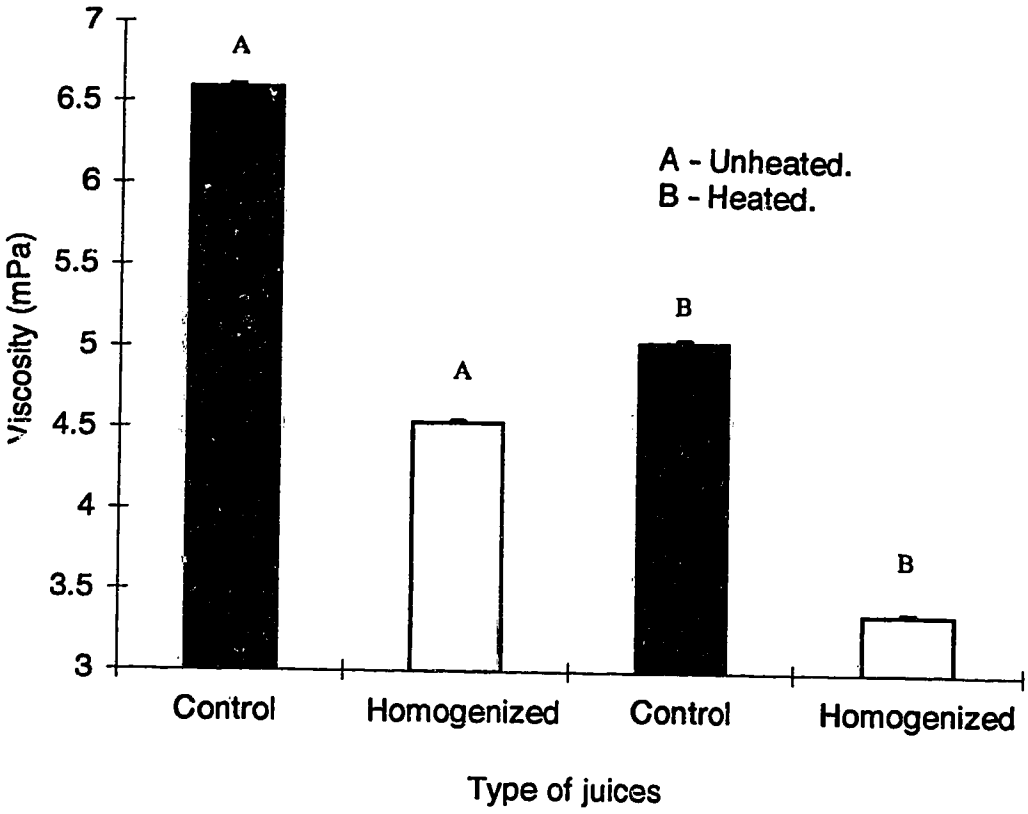


Figure 4.5.3 Effect of homogenization on the turbidity value of the whey-banana juices

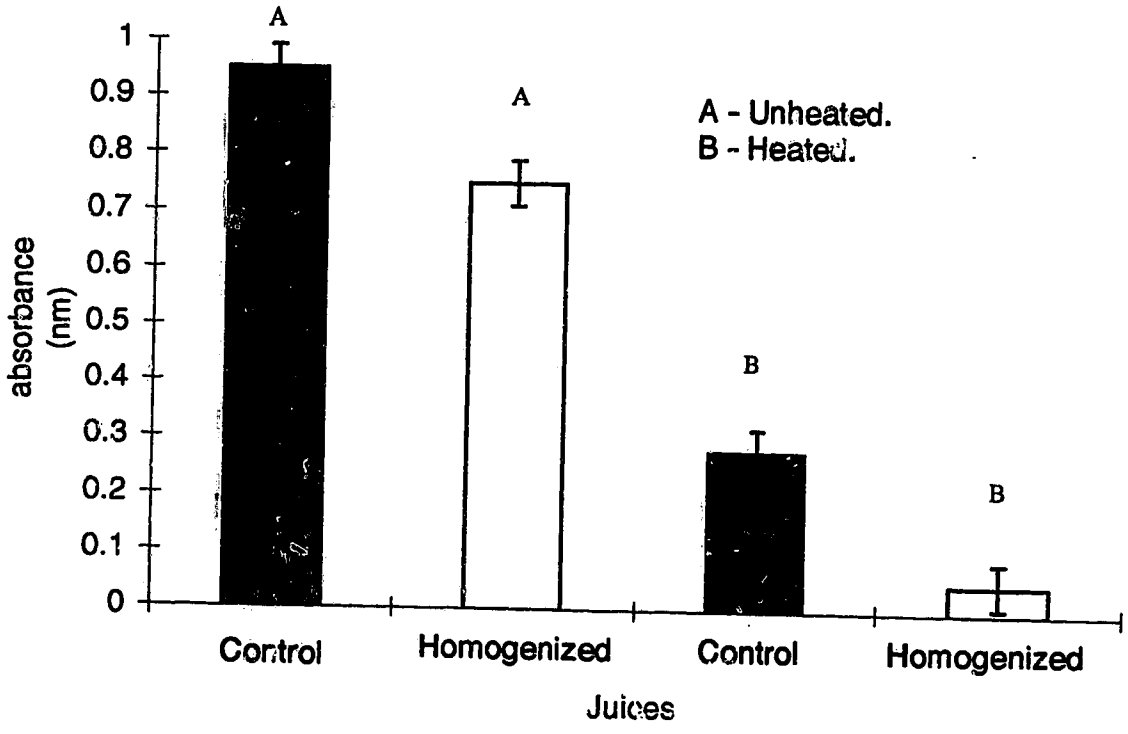
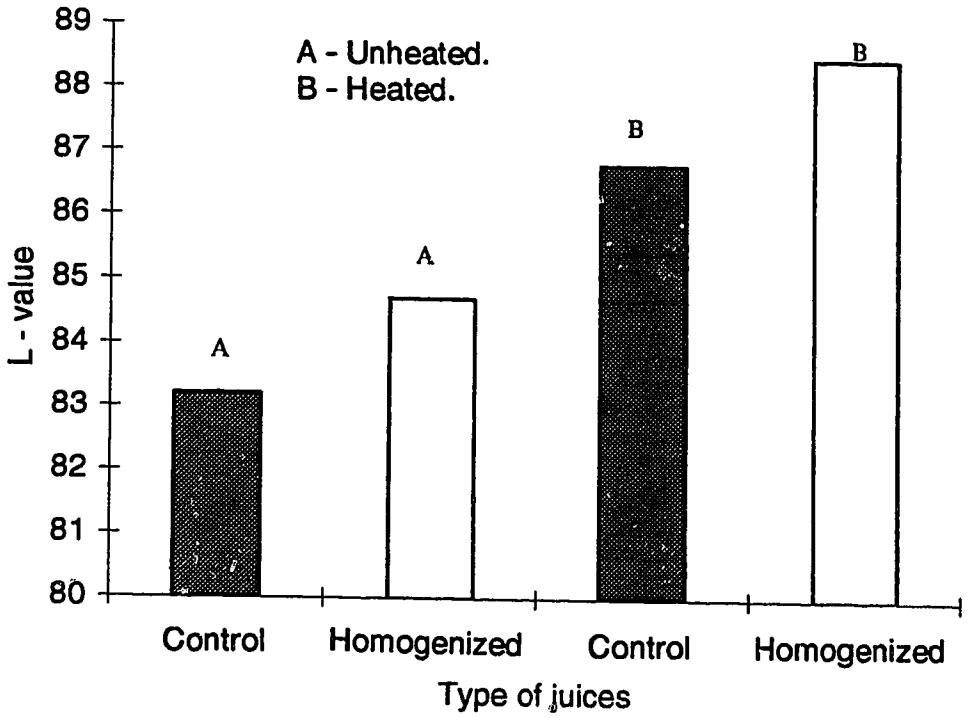


Figure 4.5.4 Effect of homogenization on L-value of the whey-banana juices



4.6 Whey-banana juice and sediment compositional analyses

4.6.1 Proximate composition

The composition of the sediments from centrifuged whey-banana shake-type products was determined in order to establish its nutritional value. The sediments obtained as a byproduct of the centrifugation of the shake-type products to obtain the juice-type products may be considered a waste. But it was observed in 4.4 that the sediment yield from CW unhomogenized beverage was

more than 50%. This prompted the need to evaluate the sediment for its nutritional value. The results summarized in Table 4.6.1 indicate that the major portion of the dry matter of the sediment was carbohydrate. The protein, fat, and ash were found to be slightly higher in the sediment than in the juices. The high protein content in the sediment may be due to colloids formed as a result of the protein-pectin, protein-tannin, and protein-starch interactions. The high amount of carbohydrate in the sediment reflects that the major portion of it consists of banana insolubles, primarily starch. Palmer (1971) stated that the major portion of ripe bananas is starch (20-25%). The juice was found to contain protein, fat, ash and carbohydrate in lower amounts than that for the sediments.

Table 4.6.1 Proximate composition of whey-banana products

Sample	*Total solids (g/100g)*	*Protein (g/100g)*	*Fat (g/100g)*	*Ash (g/100g)*	*Carbohydrate (g/100g)*
Juice-HW	8.6	0.24	0.03	0.41	7.92
Juice-CW	10.6	0.39	0.03	0.55	9.63
Sediment-HW	21.5	0.99	0.53	0.82	19.18
Sediment-CW	23.5	0.82	0.45	0.81	21.43

HW - produced from whey made with heated skim milk.
CW - produced from whey made with unheated skim milk.

4.6.2 Sugar composition

Table 4.6.1 indicated that the sediment harvested in the production of the juices contained predominantly carbohydrate. Bananas are known to contain about 12% of their carbohydrates as simple sugars (Mariott & Lancaster, 1983). Therefore, this prompted an interest in analyzing the type of sugars present in the sediments.

The results in Table 4.6.2 indicate that the juice prototype beverage prepared from both CW and HW had adequate amounts of sweetener from the bananas wherein the sugars were mainly found in the form of glucose, fructose and sucrose. The juices also contained lactose which was evenly distributed in the sediment and the juice. The reasons why fructose and glucose were found predominantly in the sediment is not known. Juices and sediment from HW did not show significant differences ($p \geq 0.05$) compared to those from CW.

Table 4.6.2 Sugar composition of whey-banana products

Sample	*Fructose (g/100g)*	*Glucose (g/100g)*	*Sucrose (g/100g)*	*Lactose (g/100g)*
Juice-HW	0.84	0.91	3.02	2.56[a]
Juice-CW	0.91	0.85	2.99	2.76
Sediment-HW	3.31	4.06	0.10	2.48
Sediment-CW	3.47	4.04	0.16	2.69

[a] Single analysis.
HW - produced from whey made with heated skim milk.
CW - produced from whey made with unheated skim milk.

4.6.3 Mineral composition

The mineral composition of both juices and sediments were as shown in Table 4.6.3. The mineral analysis for both the juice-type beverages and the sediments showed that the heating of skim milk did not affect the amount of minerals, except for calcium, which was found to be higher in both CW juice and CW sediment. The prototype juices developed were found to be a good source of calcium, sodium and potassium.

Table 4.6.3 Mineral composition of whey-banana products

Sample	*Ca (mg/100 g)*	*Na (mg/100 g)*	*K (mg/100 g)*	*Mg (mg/100 g)*	*S (mg/100 g)*
Juice-HW	27.0	9.0	73.0	7.0	3.0
Juice-CW	31.0	11.0	80.0	7.0	2.0
Sediment-HW	36.0	11.0	76.0	7.0	12.0
Sediment-CW	56.0	13.0	87.0	8.0	11.0

HW - produced from whey made with heated skim milk.
CW - produced from whey made with unheated skim milk.

4.6.4 Effect of stabilizers on visual stability of whey-banana shakes

The results in Table 4.6.4 show the average amounts of whey separated from the shake-type products recorded after 24 hours of storage. The aim of this study was to determine whether the use of stabilization technology could solve

the problem of sediment formation in the shake-type products. Originally, four products were tested. A preliminary study eliminated the possible use of two xanthan gum products (KelcoGel F and Kelcoloid LVF) since a substantial amount of whey was observed to separate immediately on standing. The xanthan gums Keltrol RD and Keltrol T were tested and resulted in no appreciable amount of whey separating when the two stabilizers were used at levels of 0.2 and 0.3% (w/w) in the samples. The samples which contain 0.1% Keltrol T appeared to exhibit a noticeable amount of separation on standing for 24 hours. Therefore, levels of 0.2% (w/w) of Keltrol RD and Keltrol T were chosen for use. This is in agreement with Towler (1984) who suggested that the appropriate level of stabilizer used is when the viscosity is at the minimum.

Table 4.6.4 Visual stability of whey-banana shakes with stabilizers stored at 4°C

%w/w / *Stabilizer*	0.1 mL whey/10mL[1]	0.2 mL whey/10mL	0.3 mL whey/10mL
Keltrol RD	0[a]	0[a]	<0.5[a]
Keltrol T	1.5[b]	0[a]	0[a]

[a,b] Data sharing a common letter are not statistically significantly different ($p \geq 0.05$).
[1] Volume (mL) of whey separated from shake per 10mL.

4.7 Sensory evaluation of the whey-banana beverages

4.7.1 Preliminary evaluations

A preliminary evaluation was carried out after the production of the prototype whey banana juices, whereby the juice and shake-type products were evaluated for preference using a 9 point hedonic scale (where 1 = dislike extremely and 9 = like extremely) to indicate which of the two types made was more suitable for further study. Four juices and four shakes were evaluated. The results shown in Table 4.7.1 indicated that the panelists did not see any significant difference ($p \geq 0.05$) among the four shakes. However, among the juices there was a significant difference ($p \leq 0.05$) indicating that HW homogenized juice was significantly less acceptable than HW unhomogenized juice. There was no significant difference between the homogenized and unhomogenized CW juices. The results indicated that the panelists preferred the juices without the homogenization process.

Table 4.7.1 Sensory evaluation of acceptability of whey-banana juices and shakes

Product	Juices (n=22)		Shakes (n=18)	
Treatments	unhomogenized	homogenized	unhomogenized	homogenized
CW	8.7[a]	7.9[a]	6.1[a]	6.5[a]
HW	8.9[a]	6.1[b]	6.2[a]	7.0[a]

[a,b] Means followed by the same letter in a column or row are not significantly different ($p \geq 0.05$).

Among the shake beverages there was no statistically significant difference ($p \geq 0.05$). However, those that were made with homogenization received higher rating compared to the unhomogenized shakes. This might be due to the fact that the homogenization process, due to the high pressure used, would break apart the large agglomerates producing an even particle size and smooth textured product. With the shakes, the HW products were preferred to the CW products. This evaluation indicated that the juices and the HW products could be more promising than the shakes and the CW products. Therefore, the main experiment on the quality attributes and acceptance of the juice by consumers was carried out with juice-type products using the FCP method.

4.7.2 Free Choice Profiling of whey-banana juices

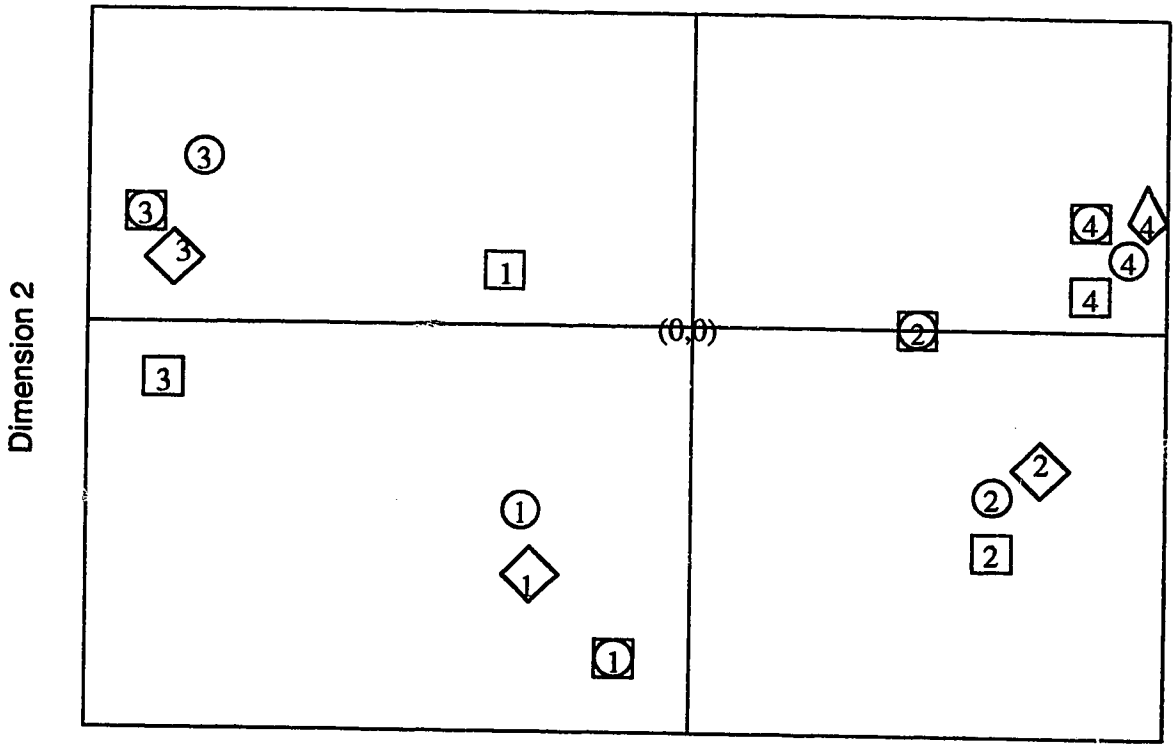
FCP was used in order to determine the likely consumer reaction to four whey-banana prototype juices produced. Twenty-four panelists assessed the whey-banana juices (Table 4.7.2) each using his/her own vocabulary. After two-dimensional analysis of the data, 75% of the results were explained by consensus plot. The distance between one juice and another and the distance between the juice and the centroid point (0,0) in the GPA consensus configuration shows the difference among the four juices (Figure 4.7.1).

Dimension 1 separates the juices by 65% while dimension 2 separates them by 15%. These results indicate that there is a large difference between

Table 4.7.2 Whey-banana juices evaluated by the Free Choice Profiling (FCP) method

Product	*Type of whey*	*Processes involved in juice manufacture*
1	heated (HW)	heated puree, unhomogenized
2	heated (HW)	heated puree, homogenized
3	heated (HW)	unheated puree with boiling whey, unhomogenized
4	unheated (CW)	heated puree, homogenized

Figure 4.7.1 Two-dimensional consensus plot for Canadian (CAN) and African (AFR) panelists for the four juices (1, 2, 3, 4) combined for two replicates (i, ii)



KEY:

AFR i = ◇1

AFR ii = ①

CAN i = □1

CAN ii = ▣1

juices 3 and 1 which are separated by dimension 1 from juices 4 and 2; these two groups differ in the use of the homogenization process. Juices 1 and 3 were produced from the unhomogenized shake-type products, while juices 2 and 4 were from homogenized shake-type products.

Dimension 2 was able to distinguish the juices depending on the type of whey used in the preparation of the shake-type starting material used for making the juices. Juices 4 and 2 differed by the type of whey used. Juice 4 was prepared from CW while juice 2 was prepared from HW. Also, dimension 2 was able to separate, by not a very large margin, juices 3 and 1 which differed depending on the method used in banana puree preparation. Heating by adding boiling whey was the method used for juice 3, while for juice 1, the banana puree was heated on a hot plate without whey.

One of the additional objectives of this study was to see if the product acceptability would be different between African and Canadian consumers depending on their cultural background. The consensus plot (Figure 4.7.1) African and the Canadian panelists positioned the juices in the xcept for juices 1 and 3 where one of the two replicates of ts placed them differently. The interchange in position of juices nave a significant effect on dimension 2 because only 15% of ability is herein accounted for as compared to that of dimension 1 which is 65%. This is in agreement with Rozin (1995) that the sense of taste and smell are similar in all human adults negating differences among cultures as a variable of importance. At the time of the study, the participating African subjects were

living in Canada, not Africa; thus, our findings are similar to those of Bertino & Chan (1986) who found no difference between North American and Chinese students living in the USA as the Chinese students had already been influenced by the environment.

The distribution of the consensus and V_{WITHIN} for the four different whey banana juices is shown in Table 4.7.3. The results show that juice 3 contributed to a greater variation with high consensus percentage among juices, followed by juices 4, 2, and last by 1. Juice 3 was the only juice prepared by mixing banana puree with boiling whey in preparation of the shakes, while the rest were prepared by the heated puree method in the preparation of the shakes. Having a larger consensus variance means the juice fits well in the consensus space when compared to others which have smaller variance (Dijksterhuis & Punter,1990).

Table 4.7.3 Consensus and variance within percentages distributed over the four juices

	Percentage variation (%)							
Panel[1] / *Juice*[2]	*Consensus*				*Variance within*			
	CANi	CANii	AFRi	AFRii	CANi	CANii	AFRi	AFRii
1	8.62	13.58	13.10	13.79	2.37	2.15	1.65	1.36
2	15.10	4.46	11.10	15.29	1.88	3.87	2.12	2.06
3	28.68	36.89	30.51	33.78	1.67	2.33	1.75	1.31
4	24.05	22.29	27.00	18.44	1.96	1.54	2.03	2.42
Total	76.45	77.24	81.72	81.31	7.89	9.89	7.54	7.15

[1] Canadian (CAN) or African (AFR) panels, 1st (i) or 2nd (ii) replicate session.
[2] See Table 4.7.2 for product definition.

The residual variance for all the juices was approximately 2% meaning that there was agreement among the panelists about the position of the products, except for juice 2 in CANii, where the variance is slightly higher meaning there was less agreement between panelists on the positioning of this juice. The consensus configuration contributed by the two dimensions were approximately 77% for the CAN panel and 81% for the AFR panel. This shows that the AFR panel perceived slightly greater variation in the juices compared to that found by the CAN panel.

When considering the individual panelists, Figures 4.7.2 and 4.7.3 show graphical representations of the distribution of V_{WITHIN} over the 12 panelists in each replicate. If the value of V_{WITHIN} is large for an individual judge, it means that this judge is not in agreement with the consensus space (Dijksterhuis & Punter, 1990).

The histograms in Figures 4.7.2 and 4.7.3 show that in both panels the panelists were not consistent between the two replicate evaluations carried out; most of them had a great loss in V_{WITHIN}. The African panelists 1, 4, 5, 6, 10, and 12 in the first replicate and 1, 2, 3, 4, and 7 in the second replicate; the Canadian panelists 1, 3, 6, 9, and 12 in the first replicate and 3 and 4 in the second replicate, are shown to have a large value of V_{WITHIN}. The histograms show a lot of variation within judges in the two panels, especially in the African panel. The use of uncommon language might be the possible reason for some of these variations. McEwan & Hallett (1990) stated that the higher the

V_{WITHIN}, the less the panelists were in agreement with the consensus space; hence, this results in a lack of fit of these panelists because of the poor reproducibil. of their results over the replicates.

Figure 4.7.2 Distribution of residual variance over 12 Canadian panelists

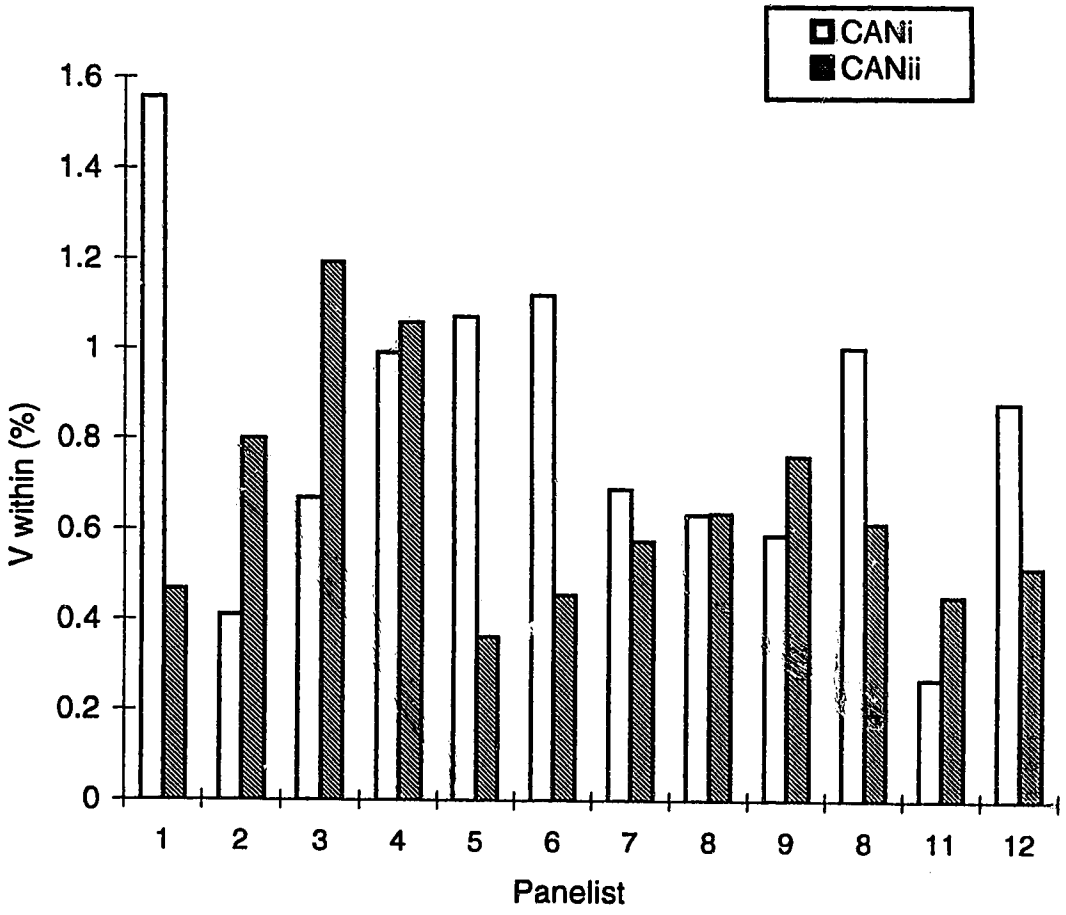
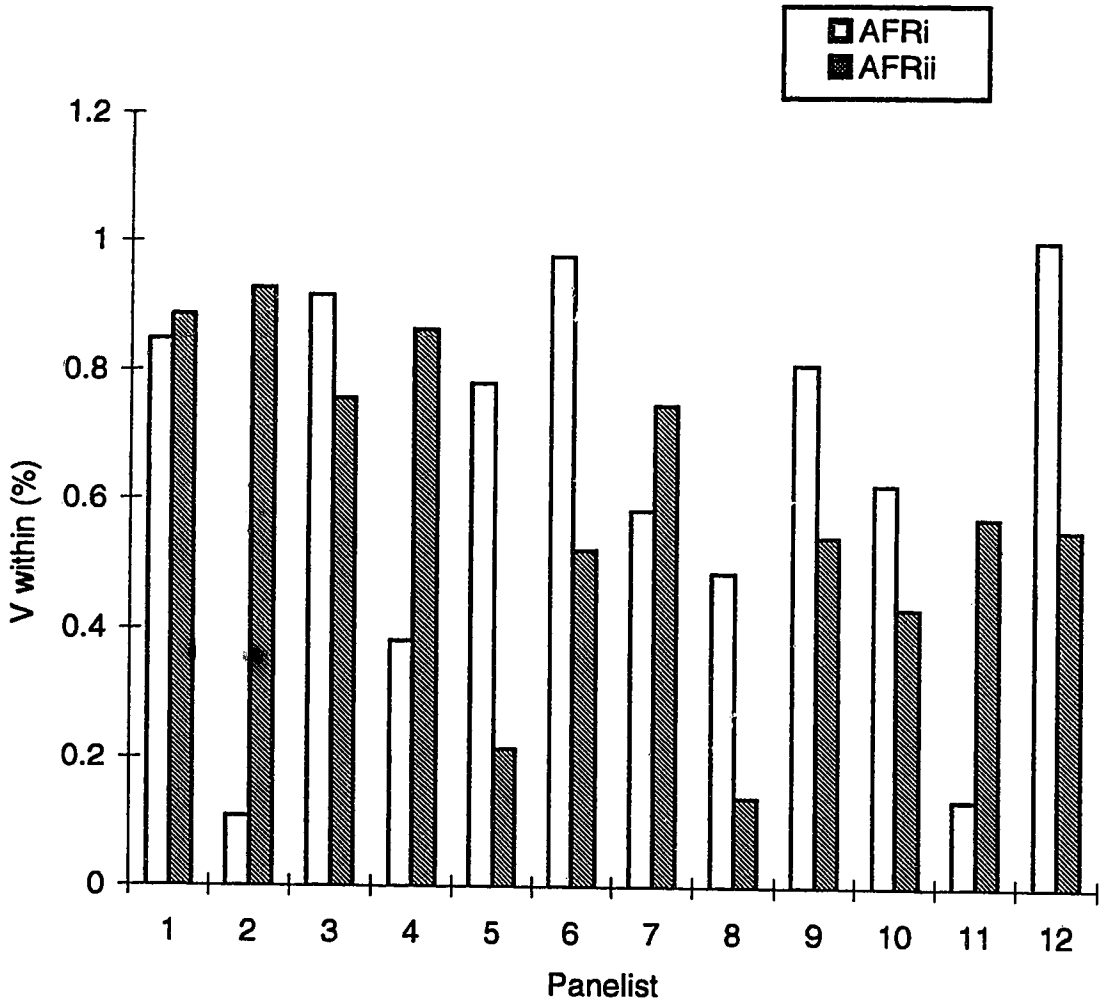


Figure 4.7.3 Distribution of residual variance over 12 African panelists



The number of terms used to describe the attributes by the Canadian panel ranged from 8 to 17 while for the African panel the range was 6 to 15. The individual attributes that were used to describe the whey-banana juices are listed in Table 4.7.4. The descriptors which were thought to refer to the same attributes were grouped together and the number of panelists who used that attribute

Table 4.7.4 Whey-banana juices: descriptive terms suggested by the panelists and the number of panelists using each term

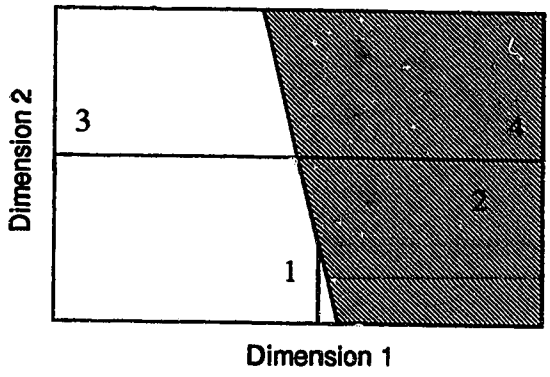
Characteristics	*Term used*	*Number of panelists*
Appearance	yellowness	22*
	clarity, bright	18*
	sediments, particles	7*
	cloudiness, white	15*
	brown, dirty	9*
	viscous, thickness	2
	champagne	1
	turbidity	1
	colour	1
Odor	banana	20*
	fruity, apple	14
	alcohol, fermentation	8
	acidity, sour	7
	sweet	5
	strength, concentration of aromatics	5
	bland, stale	4
	yeasty	2
	freshness	2
	grassy	1
	musty	1
	rancid	1
	sunflower, nutty	1
Taste	acid, sour	11
	sweet	15*
	salty	7
	fruity, apple	7
	banana	12*
	strength, concentration of aromatics	3
	whey	2
	fresh	1
	overripe	1
	stale wine	1
Aftertaste	astringency, dry, methina, starchy, ukakasi	12
	viscous, thickness	12
	bitter	4
	syrupy, sticky	3
	banana	4
	smooth, softness	3

*Terms which differentiated the juices.

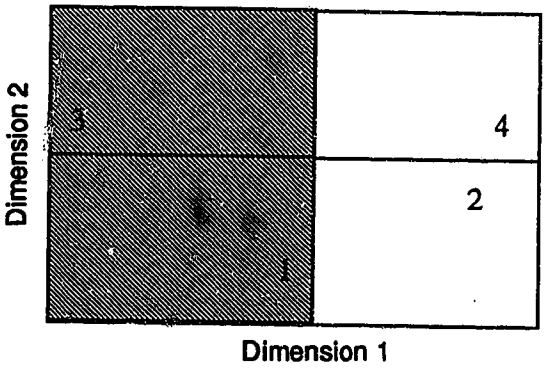
descriptor is shown. Most of the terms which were used by the Canadian panelists were also used by the African panelists. Attributes such as yellow, clarity, sediments, particles, sweet, banana, fruity, astringency and viscous were used by the same number of panelists in both panels. Other terms like grassy, musty, sunflower, nutty, whey were not terms used by the African panel. These terms were either not familiar to the African panelists or are terms not used to express such attributes. The terms acidic and sour in the taste characteristics were not picked up by any of the African panelists, while only one Canadian panelist noted an alcohol attribute. This is in agreement with Rozin & Schiller (1980) who found that the degree of usage of a product can have an effect on the evaluation. The African panelists familiar with banana beer might have associated the whey-banana juices with it. The problem of language was also observed in this evaluation (Bertino & Chan, 1986; Prescott & Bell, 1995); descriptors like *methina* and *ukakasi* which do not have synonyms in English among the terms used by the African panelists.

Those terms which differentiated the four juices were combined and plotted in the consensus space (Figure 4.7.4). Juice 3 was perceived to have banana and sweet taste, banana and sweet odor and an aftertaste; it was yellow in colour and clear in appearance. Juice 1 was perceived as being the same as juice 3 except it was described as not as yellow in colour and not clear. Juices 4 and 2 were characterized by their brown colour, cloudiness and sedimentation. The whey-banana beverages had a fruity flavor and an acid taste; the acid attribute was likely associated with the whey.

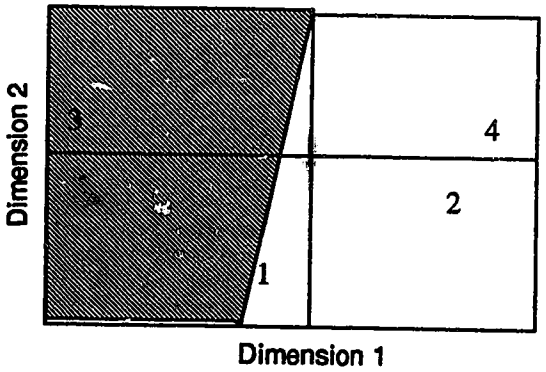
Figure 4.7.4 Location of common FCP attributes described for four whey-banana juices



Brownish sediment, particles and cloudiness



Banana and sweet taste, odor and aftertaste



Yellow, clear and clean

The evaluation of overall acceptance (Table 4.7.5) indicated juice 3, made from HW and puree heated by adding boiling whey without using homogenization, was much better accepted by both panels as it received a higher rating, followed by juices 1, 2 and 4. The juices differed significantly at $p \leq 0.05$. When comparing juices 1 and 3, it can be seen that the juice made by heating the banana puree by adding boiling whey received a slightly higher rating to that made by heating puree on a hot plate. Also, juice 2, made with HW, received a better rating than juice 4, made with CW. In this hedonic rating there was no difference between the two cultures; this is not in agreement with Druz & Baldwin (1982) who found that responses did show culture differences between Nigerian, Korean and United States individuals, nor with Lundgren *et al.* (1978) who found a similar situation in hedonic taste tests involving subjects from Poland, Brazil and Japan.

Table 4.7.5 Ranked means of overall acceptance for whey-banana juices

	Overall means of two replicate sessions	
Juice	*African panelists*	*Canadian panelist*
1	$7.4^{a,c}$	$6.4^{a,c}$
2	$5.1^{a,d}$	5.2^{a}
3	$8.9^{a,c}$	$7.7^{a,c}$
4	$4.9^{a,d}$	4.0^{a}

[a,b] Values followed by the same letter in the same row are not statistically significantly different ($p \geq 0.05$).
[c,d] Values followed by the same letter in the same column are not statistically significantly different ($p \geq 0.05$).

The mean scores (Table 4.7.5) given by the Canadian panelists were slightly lower than those of the African panelists; this may be due to knowledge of "what is whey" for the Canadians compared to the Africans. According to Rozin & Schiller (1980), knowledge about an ingredient can have an effect on the rating of a product. Nevertheless, when comparing the kind of whey used, HW juices (1, 2 and 3) rated better compared to the CW juice (juice 4), which showed the highest cloudiness and sediment formation.

4.7.3 Evaluation of the whey-banana shakes made with stabilizers

Sensory evaluation of the whey-banana shake-type products with added stabilizers was carried out to see if panelists would detect positive or negative changes with the presence of a stabilizer. Stabilizers are known to change the properties of food and their taste (Walker, 1984). Two experimental shakes containing two types of a xanthan gum (Keltrol RD and Keltrol T) were evaluated in comparison to the control sample. The results are shown in Table 4.7.6 and indicate that there was no significant difference in overall acceptability between the stabilized shakes and the control indicating that the panelists did not differentiate in terms of acceptance of the shakes with or without stabilizer. This was probably because, as shown earlier, the shakes were not a very acceptable product, with or without stabilizers. There was a significant difference ($p \leq 0.05$) for the sweetness and texture of the shakes. This is in agreement with Walker (1984) and Launay & Pasquet (1982) who explained that gums have an effect on

the perceived sweetness, aroma and flavour, due to increased viscosity and the vapour pressure of aroma volatiles. The thickness of the shakes also increased significantly ($p \leq 0.01$) but this outcome was expected as one of the functions of a stabilizer is to increase the viscosity of the medium to hold particles in suspension.

Table 4.7.6 Effect of stabilizers on the sensory properties of whey-banana shakes

Stabilizer used	*Texture*	*Sweetness*	*Flavour*	*Preference*
control	9.70[a]	6.20[b]	5.60	5.30
KeltrolT(0.2%)	4.53	5.37	5.48	5.29
[illegible]olRD(0.2%)	4.20	5.25	5.52	5.60

[illegible]s represent scores on a 15cm line. The higher the score the more extreme the attribute.
[illegible]gnificantly different at $p \leq 0.01$.
[b] Significantly different at $p \leq 0.05$.

CHAPTER 5: SUMMARY OF RESEARCH FINDINGS, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

5.1 Summary of research findings and conclusions

In this study, one of the possible ways to utilize whey and overripe bananas that are being discarded as waste was investigated by combining both into whey-banana beverages. Two types of thirst-quenching, nutritious beverages were produced: whey-banana shakes and juices. The two products were produced using 2 parts of heat-treated banana puree to 3 parts acid whey. The shake-type product was simply a mixture of whey and banana, while the juice product was made from the same shake-type product but centrifuged to remove sediment.

The rapid browning observed in the manufacturing of these products was controlled by treating the banana puree with heat before mixing with the whey. An alternative method of heating the banana puree by adding boiling whey was also found to be effective.

In the process of producing a juice product, a substantial amount of sediment was harvested from the centrifugation process. Investigation of these sediments revealed that most of their contents were insoluble components from

the bananas. The components of the sediment included: complex carbohydrate, protein, fat and ash, and the sugars lactose, fructose, sucrose and glucose. Fructose and glucose were found at higher levels in the sediment when compared to the juice; the minerals contained in the sediment were Ca, Na, K, Mg and S.

The heating of milk in a country like Tanzania is a usual practice for handling of the milk supply. The effect of heating of skim milk before the preparation of the whey used in this study was found to reduce the viscosity as well as the amount of sediment produced in the whey-banana shakes, while colour and turbidity was improved for the juices. The reduction of particle size by homogenization also reduced sedimentation, improved the colour and turbidity of the juices, and reduced the viscosity of both shakes and juices.

The stabilizers used were successful in preventing the amount of whey separation in the shakes. Xanthan gums (Kelco T and Kelco RD) were able to stabilize the shakes for 24 hours. The amount needed to stabilize the product was 0.2% (w/w). The addition of stabilizers to the products did not give any significant difference in their acceptability, but altered the flavour and the sweetness level of the shakes when compared to the control.

The sensory evaluation of the whey-banana products found the juices to be more likely to be accepted compared to the shakes. Beverages made from HW whey were much better liked than those made from CW whey.

Further evaluation on the response of possible consumers using the consumer panel in FCP, indicated a consensus agreement on the beverages

made from banana puree blended with HW, heated by mixing with boiling whey and not homogenized. There was no cultural or geographical difference between the Canadian and the African panel in placing and ranking the products, but differences were shown in the rating of the products.

5.2 Recommendations for future research

The possible interactions occurring between the whey and banana components in the CW products probably resulted in high turbidity and viscosity values for these products and this needs to be further investigated.

The sediment harvested in the preparation of the juices was found to contain components which could be beneficial if utilized in human food. Thus, further possible uses for the sediment need to be developed. One of the possible alternatives is either to use it as a baby food or incorporate it in other food formulations. The use of enzymes or other means to make the banana puree more soluble in whey could be beneficial; suitable enzymes that need to be investigated include amylase and pectinase to degrade starch, pectin and other components. An investigation is needed to ascertain why the amount of glucose and fructose found in the sediment was higher than in the juice.

The shelf-life stability of the whey-banana beverages during storage needs to be improved as the drinks were observed to deteriorate relatively quickly. Sterilization of the products and the effects of such techniques on the properties of the beverages needs further research. Aseptic packaging may be

one of the solutions to prolong the shelf-life of such a product but it is not an answer at the present time for such a product in a developing country. Sensory evaluations should be carried out in a typical African setting where there are no influences of the environment on the African panelists. As well, it would be worthwhile to consider vocabulary development using terminology that may be different from those descriptors more common to the English vocabulary.

Lastly, the practicality and applicability of the production of whey-banana beverages as investigated in the present study appears feasible for implementation on a small scale, and in a developing country using local means. This should be of great significance for a country such as Tanzania where the additional nutrient supply in the form of a nutritious whey-banana beverage could greatly contribute to alleviation of malnutrition, and thus improve the well-being of the local population.

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