DEVELOPMENT OF FLAVOURED ICE MILK, USING THE CULTURED MILK PRODUCT "MALA" AND LOCALLY AVAILABLE FRUIT JUICES/PULPS AS RAW MATERIALS

BY

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ABSTRACT

Analytical data and label information of a European yoghurt-based ice milk product was used as a basis for development of an ice milk using the cultured milk product Mala and locally available fruits as flavours. The product was prepared with varying levels of pectin, gelatine and sodium caseinate as stabilizers. The influence of varying proportions of sucrose, corn syrup and natural flavourings (mango, pineapple, passion fruit, strawberry and lemon), on the physical and sensory properties was investigated to determine their optimum levels.

Best product stability and quality were obtained with 0.3% pectin or 0.3% gelatine. Sodium caseinate improved the whipping properties of the mix but was found inferior with regard to hardness and melting properties. Pectin was selected for further investigation on account of its ready availability and compatibility with the fruit flavours.

With particular reference to sweetness and hardness, panelists rated samples containing corn syrup (CS) with a dextrose equivalent (D.E.) of 30.6 higher than those containing corn syrup of 74.7 D.E.

Best sensory and physical properties were obtained at the 25% level of substitution of sucrose with reducing sugars from corn syrup of 30.6 D.E.

For the various fruit preparations the best effects were achieved at the following levels: Mango pulp, 20%; Pineapple juice concentrate (60 ^{o}Brix), 6%; Passion fruit juice concentrate (45 ^{o}Brix), 4%; Strawberry pulp, 20% and Lemon juice, 18%.

The products flavoured with pineapple juice concentrate and mango pulp received the highest scores for taste, body and texture while those flavoured with mango pulp were scored highest for colour. The products flavoured with passion fruit concentrate were rated high for their taste and colour. Uneven colour and seed particles in strawberry pulp were found objectionable, while although having the best melting behaviour, the product flavoured with lemon juice was considered too sour.

1. INTRODUCTION

Ice milk is a frozen milk foam, typically containing less than 50% air by volume. The base of the product may be milk or a cultured milk product with a butterfat content of 3-6% (w/w).

Sales of ice cream (hard and soft-serve) are higher in the urban centres than in rural areas. The high cost of ice cream seriously limits its availability to the low income families. On the other hand, the high energy content of ice cream represents a limiting factor for sale particularly to the high income groups. There has, however, been a very remarkable increase in cultured milk consumption in Kenya's urban centres as a result of the introduction of Mala*, a cultured milk product, from whole or partially skimmed milk.

More research in nutritious dairy products with lower energy contents and available at lower prices represents a particular challenge in Kenya and other developing countries. At the moment, Kenya is on the verge of intensified livestock production and thus increased milk supply. Cultured milk products provide topics for particularly rewarding dairy research. This will also be in keeping with the traditional preference for cultured milk products in our society.

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* Registered trade name of the Kenya Cooperative Creameries, 1975 (KCC) for cultured milk product.

In Kenya incorporation of the cultured milk product Mala in ice milk is of special interest. Such a product can be prepared with the same equipment as ice cream, and pass through the same distribution channels, viz. supermarkets, health food stores and street vendors. Sale outlets in cities and market centres would comprise restaurants and ice cream parlours.

The project under reference was therefore undertaken with the following objectives:-

(1) To develop a cultured ice milk based on Mala with not less that 3.25% butterfat (minimum standard for full-cream milk in Kenya).

(2) To investigate the effect of substituting sucrose with corn syrup, and of stabilizers on the physical properties of the basic mix.

(3) To determine the most acceptable levels of some local fruits as flavours.

(4) To determine the acceptability of cultured ice milks flavoured with different fruit products by Kenyans.

2. LITERATURE REVIEW

2.1. CLASSIFICATION, STANDARDS AND LEGISLATION OF FROZEN DAIRY DESSERTS

2.1.1. Classification of Frozen Dairy Desserts

In general dairy frozen desserts, frozen foods made from a variety of dairy products, are milk with different levels of butterfat together with non-fat milk solids, sugar, flavourings, colourings, stabilizers; with or without addition of eggs, fruits, nuts, etc. The products are manufactured by forming a homogeneous mix to which air is incorporated by whipping or stirring during the freezing process (8).

Ready-to-eat frozen dairy products have been classified in different ways. At the turn of the century classification was based on whether the product did or did not contain eggs (8). Later on, commercial practices led to more elaborate groupings. Recent classification is influenced by standards of raw materials and by commercial practices.

In 1976, the U.S. Food and Drug Administration (29) distinguished the following categories of frozen dairy products:-

(1) Ice cream

(2) Frozen custard

(3) French ice cream and French custard ice cream

(4) Ice milk or milk ice

(5) Fruit sherbet

(6) Water ice.

Examples of the composition and food value of these products are presented in Table 1. In the mean-time, further categories of dairy frozen products have been introduced into the industry, including soft-serve ice products, vegetable fat-based imitation ice products and frozen yoghurt (8). These have in turn provoked research into other product categories.

2.1.2. Legal Standards for Ice Milks

Legal standards for ice milk show national and international variations. The Kenya Bureau of Standards has formulated minimum compositional standards for dairy ice milk which is 8% milk-solids-not-fat (MSNF) and 3% butter-fat (BF), with 23% sugar; excluding lactose (44). In addition, the product must be free from pathogens and faecal coliforms, while the total plate count should not exceed 100,000 per ml.

According to Arbuckle (8), it is commonly agreed that ice milk is a product containing 2-7% fat and 11-14% total milk solids (TMS), which is sweetened, flavoured and frozen like ice cream. Rothwell (71) suggested that ice milk should contain more than 7% MSNF and more than 2.5% BF.

Table 1: Levels of some components of commercial ice cream and related products (8)

	g/100g					mg/100g			Iu/100g		
	Total solids	Protein	Fat	Carbo-hydrates	Energy (J/100g)	Calcium	Phosphorous	Sodium	Vitamin A	Vitamin D	Normal serving size(g)
Vanilla ice cream	38.3	4.1	12	20.7	872.7	122.2	105	60	492	4.4	90
Chocolate ice cream	41.6	3.6	11	24.4	88.2	133.3	120	52.2	386.7	4.4	90
Strawberry ice cream	38.9	3.2	9	23.3	756	110	93.3	44.4	377.8	3.3	90
Vanilla ice milk	34	5.7	4	23.1	634.7	210	157.8	83.3	167.8	1.1	90
Orange sherbet	34.7	1.2	1.1	32.2	604.4	43.1	33.3	17.1	63.3	trace	123
Orange ice	37	0.1	--	35.4	604.4	0.8	1.6	trace	18.9	0	123
Dietary vanilla ice cream	37	4.6	10	21.6	816.7	167.8	125.6	65.6	420	4.4	90
Dietary vanilla ice milk	33	4.9	4	23	620.7	115.6	136.7	72.2	167.8	1.1	90
Frozen dessert (vegetablefat)	38.6	4.4	10	33	840	161.1	121.1	63.3	0	0	90

The Canadian Government Specification Board (18) rules that ice milk should contain at least 10% TMS of which not less than 3.5% must be BF.

In the Netherlands, ice milk contains at least 3.7% anhydrous lactose. Additionally, the specific gravity must be at least 0.5 and the total microbial count not exceed 100,000 per ml. Use of preservatives and artificial sweeteners is prohibited (3).

According to the International Dairy Federation (40) ice milk covers edible ices with at least 3% BF and a minimum total solids content of not less than 28% (w/w).

Col et al. (21) described in a patent the formulation of an ice milk frozen confection comprising about 5.3% BF, 4.2% protein, 7.1% lactose, 10.3% corn syrup solids and 7.3% high fructose corn syrup (HFCS); with trace levels of emulsifiers, flavouring compounds and stabilizers.

Very little information is available on specific standards of cultured ice milk. Mann (56) observes that in the U.S.A., frozen yoghurt must conform to the ice milk standard of identity, excluding the total bacterial count limits. The author also reports that frozen yoghurt contains about 1.5% BF, 3.4% protein, 5.2% lactose and 24% total carbohydrates. According to Chandan (20) the stabilizer level is at most 0.6%.

A survey conducted in Europe showed yoghurt based fruit ice to contain 5% MSNF and 40-60% yoghurt added with fruit juice and sugar. The final product contained 0.92% lactic acid (67). Soft-serve yoghurt ice was composed of 2% BF, 7.2% MSNF, 9.5% cane sugar, 8.5% corn sugar, 2.6% yoghurt base and 33.3% TS, while yoghurt ice for hardening contained higher BF (3.6%) and protein (4.5%) contents (67).

2.2. INGREDIENTS OF ICE MILK MIX

The composition of ice milk mix and its manufacturing technology are similar to those of ice cream (8, 88). Properly balanced, high quality ingredients and proper processing and freezing result in high quality ice milk.

Essential and optional ingredients for ice milk include dairy and sweetening ingredients, caseinates, emulsifiers, water, egg products, stabilizers, mineral salts, water, colourings and flavourings (29). Dairy ingredients, particularly MSNF, are provided through liquid (whole or skimmed) milk and/or skim milk powder. Skim milk powder (SMP) presents a cost limitation (71). Although both high-heat and low-heat SMP can be used effectively, recent studies have shown that use of high-heat SMP leads to a higher quality product (7, 8, 71) by imparting superior whipping properties, body and texture, resistance to heat shock, as well as good storage and melting properties.

Butterfat is added as whole milk, cream, unsalted butter or butter oil. In addition, partly hydrogenated vegetable fat can be used when compounded to give sharp melting at around 30 °C (71). Butterfat is preferred for its taste, colour and adequate melting at 37 °C, without impairing a clinging "fatty sensation" in the mouth.

The major sweetener used is sucrose because of its relatively low cost; and high solubility and sweetening powers. In addition, corn syrup (produced by acid or enzyme and acid hydrolysis of corn starch) are used. A correct type of corn syrup improves the texture of the product (45, 71).

Stabilizers are used in amounts upto about 0.5% of the whole mix. Stabilizers influence ice crystallization during nucleation and hardening. Adequate stabilization is achieved through addition of hydrocolloids such as gelatine, pectin, locust bean gum, guar gum, carrageenan and carboxymethylcellulose (8).

Emulsifying agents are occasionally added to reduce surface tension and prevent fat globule agglomeration. In general, the milk for production of ice milk contains adequate levels of natural emulsifiers (milk protein, lecithin, citrates and phosphates) for adequate emulsification (8).

Most ice milks are flavoured with natural or synthetic flavours. Fruit flavours, such as lemon, strawberry, bilberry and raspberry are very popular.

Table 2 summarises the advantages and limitations of the constituents of frozen desserts.

2.3. SWEETENERS IN CULTURED ICE MILKS

Cane sugar (sucrose) is the most popular sweetener. Economic pressures are, however, causing manufacturers to modify formulations and resorting to less expensive ingredients as substitutes, without of course sacrificing product quality (5, 78). The lactose contained in the solids-not-fat (SNF) serves as the substitute for lactose in milk while corn syrup (CS) serves as substitute for sucrose (78).

2.3.1. Effects of Sweeteners on Product Quality

Sugars are important for their sweetness and physico-chemical properties, particularly for depressing the freezing point of the mix (51,83). Each gram-molecular weight of sugar (e.g. 342g sucrose) lowers the freezing point of one litre of water by 1.86 deg.C (39). In addition, sugars produce thin mixes with slow whipping rates, smoother body and texture; and provide for faster melting on the tongue (51).

Table 2. Functions and limitations of various constituents of frozen desserts (8)

Constituent	Functions	Limitations
Milk Fat	- increases richness, produces a smooth texture, gives body to product.	- cost factor, reduces whipping quality, limits amount consumed primarily due to high energy levels.
Milk-Solids-not-fat	- give body, improve texture and increase overrun	- cause sandiness, salty and burnt flavour.
Sugars	- Provide solids, enhance flavour and improve texture.	- cause excessive sweetness, lower whipping quality and lengthen freezing time. Also lower temperature required for hardening.
Stabilizers	- give body and smoothen texture	- produce excessive body and melting resistance.
Total solids	- smoothen texture and improve body. Also reduce feeling of cold.	- cost factor, cause heavy soggy body and reduce cooling effect.
Flavour	- increase acceptability	- harsh flavour less desirable, intense flavour less desirable.
Colour	- improves attractiveness and aids in identifying flavour.	- intense colours impart impression of artificiality.

Frozen desserts with a lower freezing point stand increased risks of heat shock and adverse softening in conventional home freezers. On the other hand, a high freezing point results in a product that is too hard (10,19).

Arbuckle (8) observed that sucrose as the only source of sugar in ices and sherbets tends to crystallize on the surface of the product, thereby reducing homogeneity.

Use of corn syrups in frozen desserts has been reported by various authors (25, 27, 82, 92). Corn syrups impart firmer and heavier body, present an economical source of solids and increase the resistance of the finished product to heat shock (8). Heat shock causes ice crystals to melt and recrystallize into large crystals as the product passes through the distribution and storage chain. The large ice crystals give the product an icy or coarse mouthfeel. Other authors (53, 63) stress the improvement of meltdown properties of the product through addition of corn syrup.

Corn syrup reduces crystallization of sucrose on the surface of ices and sherbets. Wittinger and Smith (91) report that low dextrose-equivalent corn syrups produce smoother products with increased resistance to heat shock and improved meltdown properties. On the other hand, high fructose corn syrups provide sweetness comparable to sucrose and with minimal changes in product properties.

Substitution of sucrose with corn syrup offers cost and functional advantages (53,91). The oligosaccharides (maltose, malto-dextrins) in corn syrup bind water, increase the viscosity of the water phase and this contributes to the chewiness or firmness and the body of the products (32,87).

Viscosity and freezing point data for various combinations of sweeteners have been reported (77,78). According to Dziedzic and Kearsley (27), low dextrose equivalent corn syrups are more viscous due to their high levels of oligosaccharides, and less sweet and less fermentable due to their low levels of monosaccharides. They make for lower osmotic pressure and contribute less to browning reactions than high dextrose corn syrups.

The viscosity of a mix containing glucose syrup is directly proportional to its concentration but inversely proportional to the D.E. and the temperature. This has been shown in experiments carried out with corn syrups at different dextrose equivalents (78).

2.3.2. Levels of Sweeteners Used

According to Arbuckle (8) the desirable sucrose level is about 15%. Depending on the desired sweetness, 25% to 50% of this sucrose can be replaced with sugars from corn syrup. This is equivalent to 1.5

kg of corn syrup of intermediate conversion rate (D.E.= 52) replacing 1.0 kg sucrose (8).

Use of 9.5% sucrose and 8.5% corn syrup in yoghurt ice has been suggested (4, 67). Dziedzic and Kearsley (27) specifically suggested that 25% of the total sweetness can be supplied by corn syrup. Ice milk may also contain 9.5% high fructose corn syrup and 7.5% of a 36-D.E. corn syrup (58). Sherbets contain 14-20% sugar with 9% corn syrup (71).

2.4. USE OF STABILIZERS IN CULTURED ICE MILKS

Stabilizers are hydrophilic materials which have several functions in frozen desserts. They retard and regulate the initiation and growth of ice crystals, increase mix viscosity, improve aeration and body, and control the rate of meltdown. Stabilizers will hydrate when added to water. This leads to formation of hydrogen bonds which results in a three dimensional "matrix" throughout the liquid, thus reducing the mobility of the remaining unbound water (13, 23, 32).

Most stabilizers used are of natural origin, with some like low methoxylated pectin and carboxymethylcellulose (CMC) being only chemically modified natural products. The majority are polysaccharides of plant origin, although some like gelatine and sodium caseinate are derived from animal proteins.

2.4.1. Influence of Stabilizers on Product Properties

Moss (62) stated that properly stabilized products will have heavier body, taste less cold and melt down to a creamier consistency.

The basic role of hydrophilic gums is to reduce the proportion of free water in the mix (35), especially during aging, by converting it to the bound form. A low free water content results in smaller initial crystals during the rapid freezing process. Ice crystals of diameter less than 35 microns lead to a smooth product (13, 14).

Shipe et al. (76) found that the effect of stabilizers on the freezing characteristics is associated with changes in viscosity and the rate of migration of solutes. The inhibition of migration of crystal nuclei leads to great reduction in ice crystal growth during distribution and storage of the product (8, 88, 91).

A combination of guar gum and locust bean gum increases the thermal conductivity of frozen desserts mix (12). The thermal conductivity of the mix is dependent on the amount of free water present. Stabilizers tend to increase the electrical energy required to freeze and whip the product (12). Cottrell et al. (22, 23) demonstrated the effect of stabilizers on the viscosity of ice cream mixes. Use of hydrocolloids resulted in pseudoplastic flow behaviours of the mixes (78, 91).

Rajor and Gupta (65) found that sodium alginate increased the viscosity but decreased the specific gravity of the mix. Stabilizers tend to have adverse effects on whipping quality, melting rate and acceptability of the product (65). On the other hand, they prevent heat shock by retaining the free water bound in the matrix.

Only limited studies have been carried out on the influence of the physical properties of ice milk by stabilizers.

2.4.2. Levels of Application of Stabilizers

Levels and type of stabilizer required in ice milk vary mainly with its composition and aging, as well as with processing times and temperatures (8). Other factors to be considered include: ease of air incorporation into the mix, effect on viscosity and whipping properties, effect on meltdown characteristics, retardation of ice crystal growth and cost.

Rasic and Kurmann (67) suggested use of stabilizers at the level of 0.25% in yoghurt ice. However, the level has been varied between 0.1-0.5% (8, 58). Products with high free water contents require high levels of stabilizers (8). Sugar types containing polysaccharides have additional effects similar to stabilizers (32).

In ice milk, use of 0.18-0.25% gelatine has been reported (86). Dahle (24) indicated as suitable, addition of 0.3-0.5% gelatin of Bloom Strength 150-250 or 0.15-0.18% pectin. According to Arbuckle (8), frozen desserts (water ice and sherbets) require 0.5% low methoxylated pectin (soluble in cold water) and 0.25-0.50% gelatine of Bloom strength 250. Gelatine in ices and sherbets was criticized for causing too high overrun and poor body and texture when compared to plant derived stabilizers (8).

Small quantities of sodium caseinate have been recommended (71). Sodium caseinate is functional as a stabilizer when added to the mix at pH higher than 5.5 (31). Sodium caseinate has excellent solubility, heat stability and water adsorption (61).

Wangoh (87) found that 0.9% gelatine, 0.164% pectin or 0.6% sodium caseinate (on dry weight basis) is necessary to counteract the viscosity reduction when <u>Mala</u> is flavoured with passion fruit or pineapple juice. Gelatine, pectin and sodium caseinate are stabilizers that call for further investigations with particular reference to application in East Africa. Gelatine and pectin are presently imported, but, they are cheap and widely available. The application of sodium caseinate, on the other hand, although it can be manufactured locally, is greatly limited by ability to effect development of objectionable flavour (8,64).

2.5. FLAVOURINGS FOR CULTURED ICE MILK

2.5.1 Importance of Flavour in Ice Milk

Ice milk is valued for its flavour, cooling and refreshing effects. Popular flavouring substances are vanilla, chocolate, fruits and fruit extracts, nuts spices and sugars.

Arbuckle (8) reports vanilla, chocolate and fruits as the most dominant flavours in ice milk. Most commonly used fruit flavours include lemon, strawberry, raspberry, blueberry and bananas (4, 60).

Flavour and colour influence consumer preference and appeal, and give variety to the product (8). In an experiment, frozen yoghurts flavoured with peach, cherry or strawberry were found most acceptable while those flavoured with coffee, apple, cloud berry, grape-fruit, pineapple, pear or a banana-vanilla mixture were not as acceptable (38).

Delicate mild flavours, intense enough to be recognized, are more preferable to harsh ones. Harsh flavours are objectionable even at low concentrations (8). A study comparing the acceptability of various fruit flavours in Mala revealed that mango and strawberry were more acceptable than passion, pineapple and banana (87).

Flavour regulation is highly dependent on temperature in frozen dairy desserts. Reid and Arbuckle (68) found that consumers liked frozen products when served at -13.5 °C. The flavour was more pronounced when the temperature was increased form -14.5 °C to - 8 °C. However, products of high sugar levels or intense flavours were rated as best when served at temperatures lower than -13.5 °C.

2.5.2. Levels of Flavours used in Ice Milks

Sugar levels of 17% have been found to be the most preferred for fruit flavoured ice cream (9). Cultured ice milk would require higher levels of sugar to adjust the sugar/acid ratio to the desired level.

Preprepared and aged fruit-sugar mix is most desirable when containing sugars at the rate of 15-20% (8,20). Common fruit: sugar ratios in mixes are 3:1 for strawberry, 5:1 for lemon and 4:1 for pineapple (8). The amount of sugar added with the fruit must be accounted for during the preparation of the basic mix. A greater amount of fruit is often required to obtain the desired flavour intensity when a puree or pulp is used. Fruit concentrates present valuable and economical means of improving flavour of dairy frozen desserts.

In ice cream, the optimum level for strawberry is 15% of 2:1 to 3:1 fruit pack and 12-15% (plus added colour) of 4:1 pineapple fruit pack (8).

Work by Wangoh (87) showed that optimum flavouring levels for Mala were: 18% mango pulp, 12% passion fruit juice (14 °Brix), 18% banana pulp, 20% strawberry pulp and 16% pineapple juice-cum-tidbits.

Natural fruit flavours maintain their characteristics for over 12 months when stored in closed containers at 8-12 °C (67).

2.6. VISCOSITY OF ICE MILK MIXES

Changes in viscosity of frozen milk products have been correlated with changes in rate of freezing and ice crystal growth (45, 76). Viscosity and ice crystal size affect the texture and shelf-life of the frozen dessert (11, 78).

2.6.1. Definition and Measurement of Viscosity

Viscosity, the resistance of a fluid to flow, is the internal resistance to sliding, of one part of the fluid over another. Fluids are classified as either Newtonian or non-Newtonian. Newtonian fluids are those whose viscosity is independent on the shear rate and their rate of flow is proportional to shear stress. Non-Newtonian fluids are those whose rate of shear depends on shear stress and/or time (88).

Several methods have been used to measure viscosity of fluids. Torsion spring (coaxial) and capillary viscometers can be used to measure viscosity of cultured dairy products with a stirred curd (26, 43, 48, 80).

Ice cream mix, yoghurt and sour cream exhibit non-Newtonian behaviour. Yoghurt shows some degree of pseudoplasticity (43). Viscosity is affected by treatment of the curd, temperature and the conditions under which measurements are made (80). The viscosity of buttermilk curd as measured by a Brookfield torsion viscometer was always higher after stirring at 500 rpm for 1 minute (43).

2.6.2. Optimisation of Viscosity of Cultured Ice Milk Mixes

Viscosity has been considered an important property in frozen dessert mixes, and a certain level of viscosity appears essential for retention of air after whipping (8). Alternatives for achieving the desired viscosity in cultured dairy products are; increasing total solids, addition of stabilizers, use of specific cultures, temperature adjustment and the method of processing and handling of the mix.

Levels of 12-16% SNF are considered adequate for achieving a good viscosity in yoghurt (56). A level of 11.5% SNF has been recommended by Kurwijila (50) as optimum for Mala from skimmed milk.

Unpublished work done in the Department of Food Technology and Nutrition, University of Nairobi, showed that BF, SNF and sodium caseinate are important in influencing the viscosity of Mala (34). Kenya cooperative Creameries Ltd. (K.C.C.), however, manufactures Mala from milk standardised at 2.3% BF without addition of SNF.

Raw materials used for cultured milk products are often first heated to 85 ^{o}C for 30 minutes or to 88-91 ^{o}C for 3-5 minutes (36, 49, 89). The heat treatment denatures 80% of whey proteins. The whey proteins then interact with casein particles to increase water binding capacity of casein, thereby minimising wheying-off during subsequent handling of the products (36, 50, 88).

In Switzerland, addition of upto 0.2% stabilizer in yoghurt is allowed. In U.S.A., upto 0.5% gelatine is added to yoghurt (50). Sodium caseinate at 0.7% of the milk has been shown to improve the organoleptic qualities, increase viscosity and reduce syneresis in cultured milk products (66). Tamine and Deeth (81) showed that sodium caseinate is more effective in enhancing viscosity than SMP.

Addition of heavy pulps and thick syrups to cultured milk products does not adversely affect their viscosity. However, when fruit particles are present at pH less than 3, there is a risk of wheying-off around the fruit particles, thereby lowering the overall viscosity of the product (87). Rasic and Kurmann (67) state that addition of fruit juices dilutes yoghurt, resulting in lower viscosity. Therefore such juices are rarely used. The fruit pulp or juice should just be pourable so as not to affect the product viscosity adversely (90).

While rheological properties of ice cream have been extensively studied (73, 74, 75), only limited published literature with reference to cultured ice milk is available.

2.7. OVERRUN AND WHIPPING QUALITY OF ICE MILK MIXES

2.7.1 Definition of Overrun

England (28) defined overrun as the increase in the volume of frozen dessert over the volume of the mix due to incorporation of air during freezing. Water expands on freezing and therefore contributes to overrun to a limited extent (39).

Overrun is expressed as:-

$$\frac{\text{Weight of mix} - \text{weight of ice milk}}{\text{weight of ice milk}} \cdot 100$$

where the weight of each product is the weight of a unit volume (8, 88).

2.7.2 Role of Overrun in Ice Milk Mixes

Air in ice milk provides lightness and smooth texture. Well distributed air bubbles with mean cell diameters of 60-100 microns are desirable (14).

Low overrun results in a heavy, soggy product; whereas excessive overrun leads to a fluffy product lacking in body (14).

Overruns greater than 80% lead to foamy, dry products of relatively slow melting (52). Bakshi et al. (12) showed that there was a significant influence of air in providing an insulating effect against melting of the product.

Whipping properties of mixes determine the extent of air incorporation and dispersion of the air cells. Factors influencing whipping properties have been identified as total solids, lecithin-protein complexes, sugar content, size of fat globules, processing (aging and homogenization), viscosity of the mix and the design of the whipping machine.

Cottrell et al. (23) report that stabilizers improve aeration of frozen dessert mixes. Fat destabilization and agglomeration during freezing facilitate air incorporation and improve air cell distribution (46, 48). Destabilization is greater in frozen dessert made from cream than in similar products made from butter oil (1).

The theory that fat destabilization and agglomeration improve whipping properties has been disapproved recently (15, 42). Whipping quality is assumed to be based on the cohesion (tensile strength) and strength of lamellae (border phase around air cells). According to this theory of cohesion, clumping results in weak lameallae which rapture, resulting in low overrun.

2.7.3. Degree of Whipping

According to Arbuckle (8), ice milk is whipped so as to obtain 50-80% overrun. Sherbets and ices have

30-40 % and 25-35% overruns respectively. Chandan (20) suggested 50-60% overrun for frozen yoghurt when continuous freezers were used. Batch freezers would be expected to deliver lower overruns than continuous freezers because air is incorporated under pressure (84).

The desirable overrun is 2-3 times the percentage of total solids content of the mix (8). Riedel et al. (69) recommend use of 20-45% total solids in ice milk. High overruns require high flavour dosages because the extent of flavour impact is lower too (52).

2.8. LACTIC ACID IN CULTURED ICE MILKS

The practical importance of the role of lactic cultures in cultured dairy products is well recognized.

Mesophilic lactic acid bacteria i.e., Streptococcus cremoris with or without Leuconostoc citrovorum, S. diacetilactis etc. bring about acidification in Mala by metabolising lactose to produce lactic acid. These bacteria offer some advantages over the thermophilic culture used in yoghurt in that they can be incubated at ambient temperatures (18-25 °C), and fermentation stops when a pH of 4.2-4.3 or about 1.0 - 1.2% lactic acid is attained (50).

The lactic acid so formed helps to destabilise the casein micelles as the pH approaches its isoelectric point, leading to coagulation of the milk. The calcium caseinate-phosphate complex together with lactic acid also give the pleasant acid taste to Mala and contribute to the typical "aromatic" flavour.

A pH less than 4.5 and 0.92% lactic acid have been reported in cultured ice milks (20, 67, 69).

Tamine and Deeth (81) report a slight reduction in total lactic acid production in yoghurt when 6% sugar was added to the basic mix. This fact may be important in cultured ice milk production where sugar is added prior to heat treatment and incubation. The increase in total solids results in more water being bound and made unavailable to microorganisms. By the same, solubilization increases the initial osmotic pressure, thus affecting acidification.

Though expensive, lowering of the pH can be achieved by adding 0.3 - 0.5% citric acid. The final pH adjustment is achieved by addition of fruit pulps as most fruits have a pH in the range of 3-4 (52).

2.9. PREPARATION OF ICE MILKS FROM CULTURED MILK PRODUCTS

The raw materials for preparation of ice milks must be of high quality chemically and microbiologically. The formulation of the basic mix has to take into account the legal standards, market preferences and cost and availability of raw materials.

The basic steps in the production of ice milk are: compounding of the mix, heat treatment, homogenisation, cooling, aging, flavouring, freezing, packaging, hardening and storage. Fermentation takes place after homogenisation but before cooling and aging of the mix (20, 55).

Mann (55) has reviewed methods for preparing frozen yoghurt mixes. One procedure involves preparation of a 50:50 mixture of ice cream mix and yoghurt. An alternative method involves culturing a yoghurt mix that meets the requirements of soft-serve ice milk.

In Sweden, hard-frozen yoghurt is prepared from yoghurt mix by whipping, freezing at -6 ^{o}C and hardening at -25 ^{o}C. Hard-frozen yoghurt may be prepared through culturing of yoghurt mix or blending 40 parts yoghurt with 20 parts sugar (55).

Blenford (17) reports on a yoghurt ice cream made from fresh milk, natural flavours and active yoghurt starter; with added nuts, cookies or chocolate chips. Riedel et al. (69) report a preparation where the yoghurt portion is separately inoculated and incubated prior to addition of the fruit-sugar mix.

2.9.1. Heat Treatment

An adequate heat treatment is required to pasteurize the fresh milk and the mix ingredients, and to improve the viscosity of the cultured product.

More heat is required to effectively pasteurize frozen dessert mix than milk because of the high total solids and viscosity which offer protective effects on some microorganisms. The U.S. Public Health Service recommends 79.4 °C for 29 seconds or 68.3 °C for 30 minutes as the minimum pasteurization standard for ice cream (84).

Chandan (20) recommends a heat treatment at 87.5-90.5 °C for 20-40 minutes. Mann (55) suggests heating at 76.5-82 °C for 30 minutes. Heat treatment at 82-85 °C for 30 minutes has also been reported (4).

2.9.2. Homogenisation

Homogenisation causes a high degree of fat dispersion by reducing the size of the fat globules to less than two micron (84). Arbuckle (8) states that homogenisation of ice milk retards creaming of fat, improves whipping quality and results in a smooth product. Homogenisation increases the viscosity, thereby facilitating air incorporation during the whipping process (88). Homogenisation is carried out under pressure at a temperature preferably near the pasteurization temperature because at this temperature the fat is a liquid (32). According to Webb et al. (88) homogenisation is carried out at 60-74 °C and 105-210 kg/cm^2 immediately after pasteurization. Chandan (20) homogenised frozen yoghurt mix at a temperature of 57-62.5 °C, and pressures of 105kg/cm^2 (first stage) and 35kg/cm^2 (second stage). Second stage homogenisation breaks up the fat globule clumps that form during first stage homogenisation.

Homogenisation at 120 kg/cm^2 and 140–210 kg/cm^2 depending on the fat content has been reported (32, 55, 84).

2.9.3. Inoculation and Incubation of Cultured Ice Milks

Addition of 2-5% yoghurt starter and incubation to a pH of 3.9 has been reported (4, 20, 55). Incubation time is 3-4 hours at 34.5 °C by the short set method or 18 hours at 32 °C by the long set method (20).

Riedel et al. (69) report use of 5% yoghurt starter and five hours incubation to attain a pH less than 4.5. Mann (57) reports inoculation with yoghurt culture to achieve 1.2% titratable acidity (TA).

The coagulum is broken at 22-24 °C by passing it through a homogeniser (no pressure applied) or by hand stirring (20).

2.9.4 Freezing and Hardening

The function of the freezing step is to pre-freeze and to incorporate air into the mix. Refrigeration is supplied by expanding liquid ammonia or freon at -22 °C to -32 °C (88).

During freezing, ice in the form of small crystals separates from the water in the mix, thus increasing the viscosity of the unfrozen portion. The unfrozen mass is finally extruded from the freezer at -5 °C to -6 °C as a stiff, plastic stream (soft-ice) for packaging (88).

Hardening of the packaged soft-ice is accomplished at -30 ^{o}C to -40 ^{o}C in 4-12 hours depending on the rate of heat removal (8, 32, 88). Ice crystal growth is allowed until 80% of water is crystallized (32, 39). Storage at - 17 ^{o}C for a few months (32) and at -29 ^{o}C upto six months (57) without further changes in texture has been reported.

3. MATERIALS AND METHODS

3.1. RAW MATERIALS

3.1.1. Milk and Milk Solids

Fresh milk was obtained from farmers at the point of delivery to the K.C.C. factory Dandora, Nairobi. High heat SMP containing 97% total solids was obtained from K.C.C, Nairobi.

3.1.2 Cane Sugar

White granulated cane-sugar (sucrose) produced locally was bought from local shops. Prior to incorporation into the mix, the sugar was dissolved in some milk and screened to remove particulate matter.

3.1.3. Corn Syrups

Two types of corn syrups, a clear one of 42.96 °Baumé (Bé) and a yellow one of 43.13 °Bé were obtained from Corn Products Corporation Ltd, (CPC) Eldoret.

3.1.4. Pineapple Juice Concentrate

Pineapple juice concentrate of 60 °Brix was obtained from Kenya Canners Ltd., Thika.

3.1.5. Strawberry Pulp

Strawberries were bought locally and pulped using a Homorex mixer, then mixed with sugar at the rate of 1 kg per 3 kg pulp. The pulp was then sealed in polythene bags and stored at -18 °C until required.

3.1.6. Lemon Juice

Unsweetened lemon juice was obtained from Utopia Natural Foods Ltd., Nairobi.

3.1.7. Passion Fruit Juice Concentrate

Passion fruit juice concentrate of 45 ^{o}Brix was obtained from Kenya Fruit Processors Ltd., Thika.

3.1.8. Mango Pulp

Canned, unsweetened mango pulp was obtained from Trufoods Ltd., Nairobi.

3.1.9. Bacteria Culture

One lyophilized mesophilic lactic culture B:40, containing *Streptococcus cremoris*, *S. diacetilactis* and *Leuconostoc citrovorum* (*Betacoccus Cremoris*) was obtained from Christian Hansen's Laboratorium, Copenhagen, Denmark.

3.1.10. Commercial Ice Yoghurt

Two types of commercial ice yoghurt at two different fat levels were obtained from supermarkets in Switzerland.

3.1.11. Pectin

Slow set pectin was obtained from Trufoods Ltd., Nairobi.

3.1.12. Gelatine

Pure granulated gelatine (160-180 Bloom), Dominion brand, packed by Erskine and Price (MFG) Ltd., Nairobi, was used.

3.1.13. Lemon Yellow Food Colour (Tartrazine)

Powdered food grade lemon yellow was obtained from Erskine and Price (MFG) Ltd., Nairobi. A 2.5% colour solution was prepared by dissolving in boiling water (8).

3.2. LABORATORY CHEMICALS

All regular laboratory chemicals were of analytical grade and were purchased from Howse and McGeorge Kenya Ltd., Nairobi.

3.3. METHODS

3.3.1. Preparation of Starter Culture

Starter Culture was prepared using the method proposed by Kurwijila (50). B-CH:40 starter frozen during lag phase was thawed (3-6 hours) and four transfers done to obtain the bulk starter. For each transfer, milk was heated to 90-95 ^{o}C, held for 30 minutes and then cooled to ambient temperature. It was then inoculated with 2-3% of the previous culture, incubated at ambient temperature for 20 hours and thoroughly mixed.

3.3.2. Preparation of Sodium Caseinate

Sodium Caseinate was prepared according to the method proposed by Schulthess (72). This method involved acidification of skimmed milk by fermentation with mesophilic lactic acid bacteria to obtain acid casein. Sodium caseinate was obtained through addition of 0.05 kg $NaHCO_3$ to 1 kg acid casein on dry matter basis.

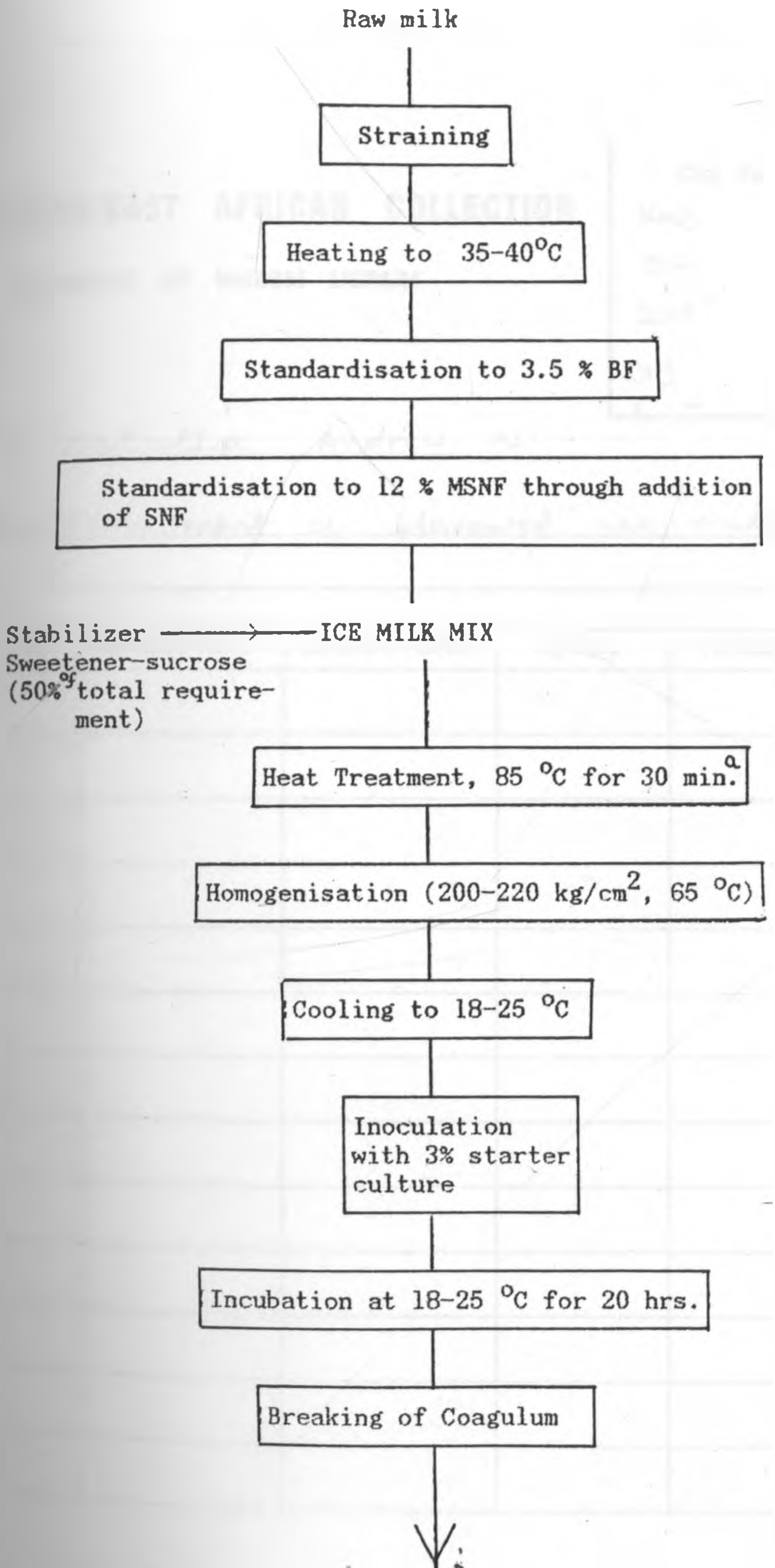
3.3.3. Preparation of Cultured Ice Milk

Cultured ice milk (standard mix) was prepared as indicated in Figure 1, following the typical cultured ice milk formulation shown in Table 3. This formulation is based on European ice yoghurts.

3.3.4. Cultured Ice Milk for Evaluation of Physical Properties

Different batches, two litres each, of cultured ice milk were prepared for testing of physical properties. To the mix were added a combination of either two or three different sweeteners (sucrose, 42.96 ^{o}Be corn syrup and/or 43.13 ^{o}Be corn syrup) and 0.5% pectin.

The sugar content in the mix was kept constant at 19%, while the ratio of sucrose to corn syrup su gars was varied as follows: 0:100, 25:75, 50:50, 75:25 and 100:0. To establish the optimum level of stabilizer, pectin, gelatine and sodium caseinate were added at the rates of 0.0, 0.2, 0.3 and 0.5%.



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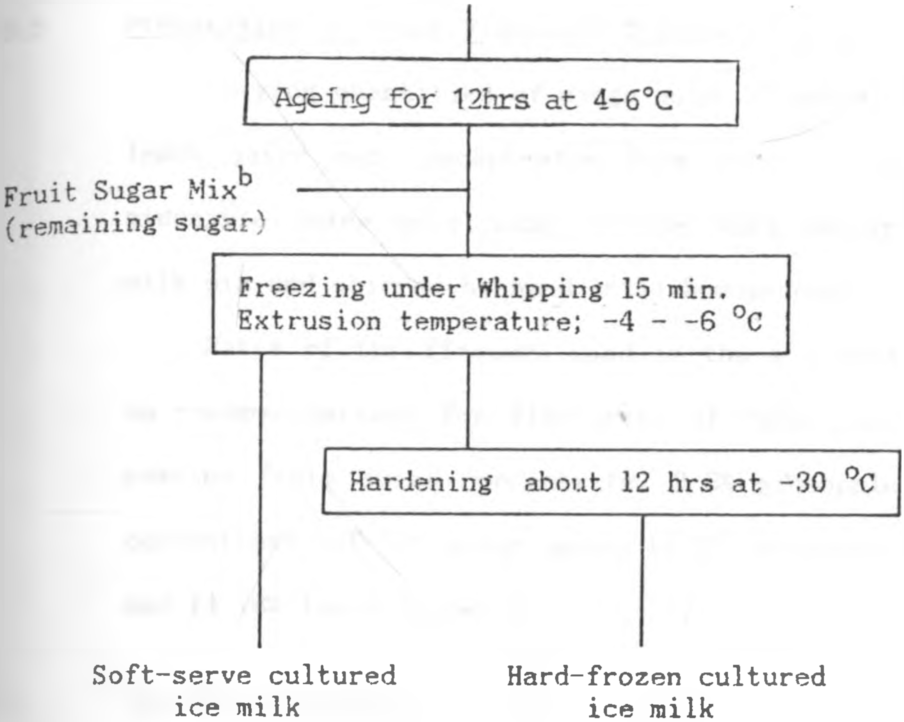

Figure 1. Cultured ice milk preparation (standard mix)

[a]Addition of 0.3% sodium caseinate at 65 °C to counteract reduction in viscosity through addition of fruit juice, as proposed by Wangoh (88).

[b]Fruit-sugar concentration dependent on specific flavour.
Food grade lemon yellow added when pineapple fruit concentrate or lemon fruit juice was used.

3.3.5 Preparation of Fruit Flavoured Cultured Ice Milk

Varying quantities of mango pulp, strawberry pulp, lemon juice and concentrates from passion fruit and pineapple juice were added to the aged cultured ice milk mix and stirred by hand until homogeneous.

Rates of the flavours used in the mix were based on recommendations for flavouring of Mala i.e. 2-6% passion fruit juice concentrate, 2-6% pineapple juice concentrate, 16-20% mango pulp, 18-22% strawberry pulp and 14-18% lemon juice (87).

3.4. ANALYTICAL METHODS

3.4.1. Analysis of the European Ice Yoghurt

Samples of the European ice yoghurt were melted and analysed as shown. The analyses were carried out in duplicates, and the results expressed on a wet weight basis:

3.4.1.1 Total solids:

Gravimetric method according to AOAC method 16.313 (6).

3.4.1.2 Fat content:

Gerber rapid method using the Gerber butyrometer.

3.4.1.3 Protein content:

Kjeldahl method (% protein = % N x 6.38) according to AOAC method 2.057 (6).

3.4.1.4 Ash content:

By thermo-gravimetric methods according to AOAC method 16.035 (6).

3.4.1.5 Total carbohyrates:

Obtained by subtraction

3.4.1.6 pH and acidity:

The pH measurements by a PYE UNICAM (Model 290 MK2) pH meter. The total titratable acidity was determined by titrating with 0.1N NaOH to pH 8.4. The results were expressed as % lactic acid.

3.4.1.7 Sugar content:

Total sugars, sucrose and reducing sugars were analysed by the Luff-Schoorl method as described in method No.4, of the International Federation of Fruit Juice Producers, (IFFJP) 1968 (41).

3.4.2. <u>Characterisation of Corn Syrup</u>

Samples of the corn syrup (CS) were analysed for their moisture contents, refractive indices and reducing sugars as follows:

3.4.2.1 Moisture content:

Vacuum-drying according to AOAC method 31.005 (6).

3.4.2.2 Refractive index:

At 20 °C with Abbé Refractometer (Kikuchi, Tokyo) according to AOAC method 31.228 (6).

3.4.2.3 Reducing sugars:

Luff-Schoorl method No.4 of International Federation of Fruit Juice Producers, IFFJP (41).

3.4.3. Testing of the Properties of the Cultured Ice Milk

3.4.3.1. Determination of pH and acidity

pH and titratable acidity were determined as indicated in section 3.4.1.

3.4.3.2 Determination of specific gravity

The specific gravity of the aged mix was determined at 20 °C with a pycnometer according to AOAC method 16.021 (6).

3.4.3.3 Determination of freezing point

The freezing point of the aged mix was determined with the Gerber cryoscope using a calibrated Beckmann thermometer. The mix was diluted two-fold prior to the determination and the dilution factors considered in the calculation of the freezing point.

3.4.3.4 Determination of relative viscosity

Relative viscosity was measured at 5 °C with a torsion viscometer (Rheomat STV, Contraves A.G., Switzerland), using either measuring system B or C, and either speed setting I, II, or III. Readings were taken 30 seconds after the spindle began to turn. The viscometer was calibrated using glycerol.

3.4.3.5 Determination of overrun

Overrun was determined by weighing in aluminium cups a fixed volume of the cultured ice milk as it was drawn from the freezer. The same volume of unfrozen mix was also weighed. Overrun was then calculated as follows:

$$\text{Overrun } \% = \frac{\text{weight per volume of unfrozen mix} - \text{weight per volume of ice milk}}{\text{weight per volume of ice milk}} . 100$$

Maximum overrun was represented by a constant weight of the ice milk for the constant volume.

3.4.3.6 Determination of the melting resistance

A 15 cm diameter tea strainer containing a cut block of 140-160 g cultured ice milk (tempered for 24 hours at -12 ^{o}C) was suspended over a large funnel, and the melted material collected. Meltdown (weight % of the cultured ice milk melted) was determined at 23$\pm$ 2 ^{o}C as a function of time.

3.4.3.7 Measurement of hardness

Samples of the cultured soft ice were filled in plastic cups upto the rim and placed in a cabinet at -30 ^{o}C overnight. They were then transferred to another cabinet and stored at -18^{o}C for a week. Thereafter, the cups were removed from the cabinet and hardness of the samples measured with a fruit pressure tester

(Model FT 327) using plunger of diameter 0.794 cm (5/16 inches) penetrating to a depth of 7mm into the ice milk. The measurements were taken within 15-20 seconds after removal from -18 °C.

3.4.4. Sensory Evaluation

3.4.4.1 Optimisation of sucrose replacement with corn syrups in the cultured ice milk

Both sensory evaluation and physical properties data were used to evaluate the optimum level of sucrose replacement by corn syrup.

The level of sucrose and/or reducing sugars was maintained at 19%. The types of two corn syrup used had 30.6 D.E. and 74.7 D.E respectively. Pectin at 0.3% was used as stabilizer.

Five levels of sucrose replacements were used viz. 0, 25, 50, 75 and 100%, and the rest of the processing procedure maintained.

Samples were presented randomly to twelve panelists who were asked to fill the questionnaire (Appendix I). Data were subjected to analysis of variance (79).

3.4.4.2. Sensory evaluation of fruit level optimisation in fruit flavoured cultured ice milk

A completely randomized design with three fruit levels was used to evaluate the optimum level of fruit used to flavour cultured ice milk. The cultured ice milk had been sweetened with optimum quantities of sucrose and corn syrup as shown in section 4.6.

The panelists, members (staff and students) of the Department of Food Technology and Nutrition, familiar with sensory evaluation of foods were asked to fill the score sheet in Appendix II. Data were subjected to analysis of Variance (79).

3.4.4.3. Sensory evaluation to determine the most acceptable fruit flavoured cultured ice milk

Cultured ice milk was flavoured with the optimal quantity of fruit determined for each fruit as indicated in section 4.7.1.

The samples were presented together to twelve panelists in a completely randomized design.

The panelists were asked to fill the score sheet (Appendix III). The results were subjected to analysis of variance (79).

4. RESULTS AND DISCUSSION

4.1 COMPOSITION OF ICE YOGHURTS

Results of the proximate analysis of two types of commercial ice yoghurts from Switzerland with two different fat contents are given in Table 4. The two types were lemon ice yoghurt (LIY) and bilberry ice yoghurt (BIY). The results represent means of duplicate analyses.

From the Table, it can be seen that the average fat content of the two samples of LIY was 3.0% BF and 6.0% BF. The low fat ice yoghurt had 34.5% TS with 5.2% protein, 1.0% ash, and 25.6% total sugars, of which 11.9% were sucrose and 13.7% reducing sugars. The titratable acidity (expressed as % lactic acid) was 1.2% while the pH was 3.6. Similar values were obtained for the product with 6% BF except for the level of total sugars which was around 3% lower.

Similarly, the two samples of BIY contained 3.0% and 6.0% BF. The average composition of the low fat BIY was 37.4% TS with 4.7% protein, 0.9% ash and 21.2% total sugars of which 11.4% were sucrose and 9.6% reducing sugars. The titratable acidity was 1.2% while the pH was 3.6. The product with 6% BF had a similar composition, but with slightly lower contents of proteins and total sugars.

Table 4. Proximate composition of European ice yoghurt mixes

Components	LIY		BIY	
	I	II	I	II
Fat (%)	3.0	6.0	3.0	6.0
Water content (%)	65.5	64.4	62.6	66.8
Total solids (%)	34.5	35.6	37.4	33.2
Proteins (%)	5.2	5.4	4.7	4.0
pH	3.6	3.7	3.6	3.9
Titratable acidity (as % lactic acid)	1.2	1.2	1.2	1.1
Total carbohydrates (%)	25.3	23.3	28.8	22.3
Total sugars (%)	25.6	22.7	21.2	20.3
Sucrose (%)	11.9	12.0	11.4	10.7
Reducing sugars (%)	13.1	10.7	9.6	9.0
Total ash (%)	1.0	0.9	0.9	0.9

LIY = Lemon ice yoghurt

BIY = Bilberry ice yoghurt

I = Low fat sample

II = High fat sample

Table 4. Proximate composition of European ice yoghurt mixes

Components	LIY		BIY	
	I	II	I	II
Fat (%)	3.0	6.0	3.0	6.0
Water content (%)	65.5	64.4	62.6	66.8
Total solids (%)	34.5	35.6	37.4	33.2
Proteins (%)	5.2	5.4	4.7	4.0
pH	3.6	3.7	3.6	3.9
Titratable acidity (as % lactic acid)	1.2	1.2	1.2	1.1
Total carbohydrates (%)	25.3	23.3	28.8	22.3
Total sugars (%)	25.6	22.7	21.2	20.3
Sucrose (%)	11.9	12.0	11.4	10.7
Reducing sugars (%)	13.1	10.7	9.6	9.0
Total ash (%)	1.0	0.9	0.9	0.9

LIY = Lemon ice yoghurt

BIY = Bilberry ice yoghurt

I = Low fat sample

II = High fat sample

Basic ingredients of commercial ice yoghurts can be estimated from their label declarations. According to the label the commercial ice yoghurts (LIY, BIY) contain 3.0% BF, 4.0% protein and 26.0% total carbohydrates in addition to stabilizers and fruit flavours. The exact composition and specific raw materials used in the manufacture are revealed by the results of the proximate analysis.

The values obtained (Table 4) agree well with data in literature. Webb et al (88) and Arbuckle (8) report 33.3% TS in ice milk. Frozen yoghurt contains 30 - 33% TS (8). Commercial ice milks contain 3 - 6% BF (8, 40, 88).

The protein content of ice milk has been reported to be in the range of 4.2 - 4.8% (7, 67, 88). Cole et al. (21) reported 4.2% protein in ice milk. Whole milk contains 3.5% protein (88). Casein comprises about 80% of the total protein, the remaining 20% being whey proteins (8). A protein content of 4.5% in ice milk can be obtained through addition of 3.3% SMP. The proximate composition of SMP and whole milk are summarised in Table 5.

The average ash content of whole milk is 0.7% (8, 88). Ash in ice milk occurs as mineral salts e.g. phosphorus, chlorine, sodium, potassium, magnessium and and traces of other salts (8).

Table 5. Proximate composition of skim milk powder (SMP) and whole milk for standardisation of ice milk mix

% of component	SMP	Whole milk
Lactose	52.3	4.8
Protein	35.9	3.5
Fat	0.8	3.5
Ash	8.0	0.7
Moisture	3.0	87.4

Some authors (8, 88) report 22.4% added carbohydrates in ice milk, of which 13 - 14% sucrose. Frozen yoghurt contains 15 - 17% sucrose (8). Mann (55) reported 24% total carbohydrates in the same product. Rasic and Kurmann (67) reported 9.5% sucrose and 8.5% corn sugar in soft-serve ice yoghurt. About 7.1% lactose, 7.3% high fructose corn syrup (HFCS) and 10.3% corn syrup solids in the same product have been mentioned. Levels of fruits added will not supply the reported levels of reducing sugars. Addition of corn syrup is therefore providing the major portion of reducing sugars in ice milk.

Many authors (4, 20, 57, 69) have reported a level of titratable acidity equivalent to 1.0 - 1.2% lactic acid and a pH of 3.9 - 4.5 in yoghurt based ice milk. Rasic and Kurmann (67) reported 0.92% lactic acid in yoghurt ice. A low pH in ice yoghurt is obtained through acidification with <u>Streptococcus thermophilus</u> and <u>Lactobacillus bulgaricus</u> (yoghurt starter culture). Addition of a food grade acid would increase the cost. By using Mala starter culture about 0.8% lactic acid can be obtained (50, 87). However addition of flavours from fairly acidic fruits such as lemon and passion fruit contributes to increase in acidity.

Our cultured ice milk was formulated on the basis of the proximate composition of the two products analysed and in conformity with the Kenyan legal standards.

4.2 CHARACTERISATION OF CORN SYRUPS

Results from analysis of a selected number of characteristics of two corn syrups manufactured in Kenya by CPC Industrial Products (Kenya) Ltd., Eldoret are shown in Table 6. The results represent means of duplicate analyses. On the whole the levels are within the limits reported in literature for commercial corn syrups used in frozen desserts (8).

4.3 PECTIN, GELATINE AND SODIUM CASEINATE APPLICATION IN CULTURED ICE MILK (CIM)

The labels on the European ice yoghurts analysed indicated that the products contained added stabilizers. However, the specific amounts and kind were not indicated. It was therefore necessary to establish the level for our formulation.

The effect of pectin, gelatine and sodium caseinate on some physical properties of CIM and CIM mix was determined. The results are shown in Table 7. Average values for pH, titratable acidity (TA), specific gravity, relative viscosity, overrun, freezing point depression and hardness are given. The effect on the melting rate is presented in Table 8.

Table 6. Selected properties of commercial corn syrups

Property	Level of total solids in corn syrups	
	42.96 °Baumé	43.13 °Baumé
Moisture content (%)	19.0	17.9
Total solids (%)	81.0	82.1
Refractive index	1.498	1.499
Reducing sugars (%)	24.8	61.9
Dextrose equivalent (D.E)	30.6	74.7
Colour	Colourless	Yellow

Increasing the level of stabilizers decreased the specific gravity of the mix.

Average viscosities as measured with a torsion viscometer at a shear rate of $24.9s^{-1}$ were between 7.7 - 14.3 poise. Addition of pectin and gelatine at the level of 0.3% resulted in products with viscosities of 10.5p and 11.00p respectively, while addition of sodium caseinate at the same level resulted in a product with a viscosity of 8.80p. Both, pectin and gelatine were found to produce the higher viscosity at 0.5% level.

Increasing the concentration of stabilizer in steps of 0.1% first decreased and then increased the relative viscosity of the aged mix (Table 7 and Fig. 2). The lowest viscosity was observed at a stabilizer concentration of 0.2%. At pectin and gelatine concentration of 0.5% the mixes had viscosities higher than those of the control samples. However, none of the the mixes was too viscous to cause difficulties in processing.

The freezing point depression varied from 2.00 to 2.44 ^{o}C. It was found that the freezing point depression was greater in mixes with high viscosity.

The decrease in specific gravity due to addition of stabilizer increased mix viscosity, which in turn increased air inclusion into the mix (65). Jain and Verma (42) reported a specific gravity of 1.086 - 1.105 for ice cream mixes.

Freezing point depression values between 2.5 deg C and 3.0 deg C have been reported (8). Increased stabilizer concentration in a mix results in increased binding of water which lowers the freezing point of the mix (88).

Changes in viscosity have been correlated with changes in rates of freezing (76, 78). Shipe et al. (76) found that the addition of gelatine depressed the freezing point and attributed this to the water-binding capacity of the gelatine. It was assumed that viscosity affected the rate of heat transfer which indirectly affected the rate of crystal growth by influencing the rate of migration of solutes.

Viscosity is mainly determined by the level of suspended colloidal particles, e.g. proteins, stabilizers and fat (65). Values ranging from 0.2 to 21.4 poise have been reported in frozen dessert mixes (42). Hydration extends the polymeric stabilizer molecules thus increasing the internal friction and thereby the apparent viscosity of the product (23).

Changes in overrun with increasing freezing time are also shown in Figures 3a-3c and 4a-4c. Generally, up to levels of about 0.3% stabilizer, the overrun increased with increasing stabilizer concentration. At 0.5% stabilizer concentration, however, the overrun was much lower than that at 0.3% stabilizer concentration with all stabilizers. The maximum overruns obtained at 0.3% stabilizer concentration was 55.8%, 54.5% and 41.5% for pectin, gelatine and sodium caseinate respectively, whereas at 0.5% concentration the overruns were 37.0%, 31.0% and 32.8% for the three stabilizers respectively.

Arbuckle (8) reported that the whipping quality of a mix is dependent on its composition, efficiency of the whipping mechanism and the viscosity of the mix. Since the whipping mechanism and average composition in the experimental mixes were constant, it can be stated that differences in the whipping quality were determined by the viscosity of the mixes. Levels of stabilizers influence the viscosity and early air incorporation into the mix (8).

Table 7. Effect of pectin, gelatine and sodium caseinate on some properties of Cultured Ice Milk

	Level and effect of Stabilizer									
	No stabilizer	% Pectin			% Gelatine			% Sodium Caseinate		
	0.0	0.2	0.3	0.5	0.2	0.3	0.5	0.2	0.3	0.5
Specific Gravity	1.091	1.052	1.054	1.072	1.072	1.054	1.048	1.052	1.069	1.074
Viscosity (poise)[a]	11.00	9.68	10.45	14.30	8.58	11.00	13.20	7.70	8.80	10.12
Depression of freezing point (deg.C)	2.00	2.10	2.20	2.38	2.00	2.04	2.10	2.10	2.36	2.64
Overrun (%)[b]	33.80	35.7	55.8	37.0	33.5	54.5	31.00	40.90	41.50	32.80
Hardness (Kg/cm^2)[c]	19.0	18.4	19.2	23.0	18.4	22.0	22.0	14.0	14.6	18.0

[a] measuring system C (torsion viscometer) at 249 s^{-1}

[b] freezing time = 15 minutes

[c] force applied to penetrate 0.7cm of product (plunger surface area = 0.5 sq. cm)

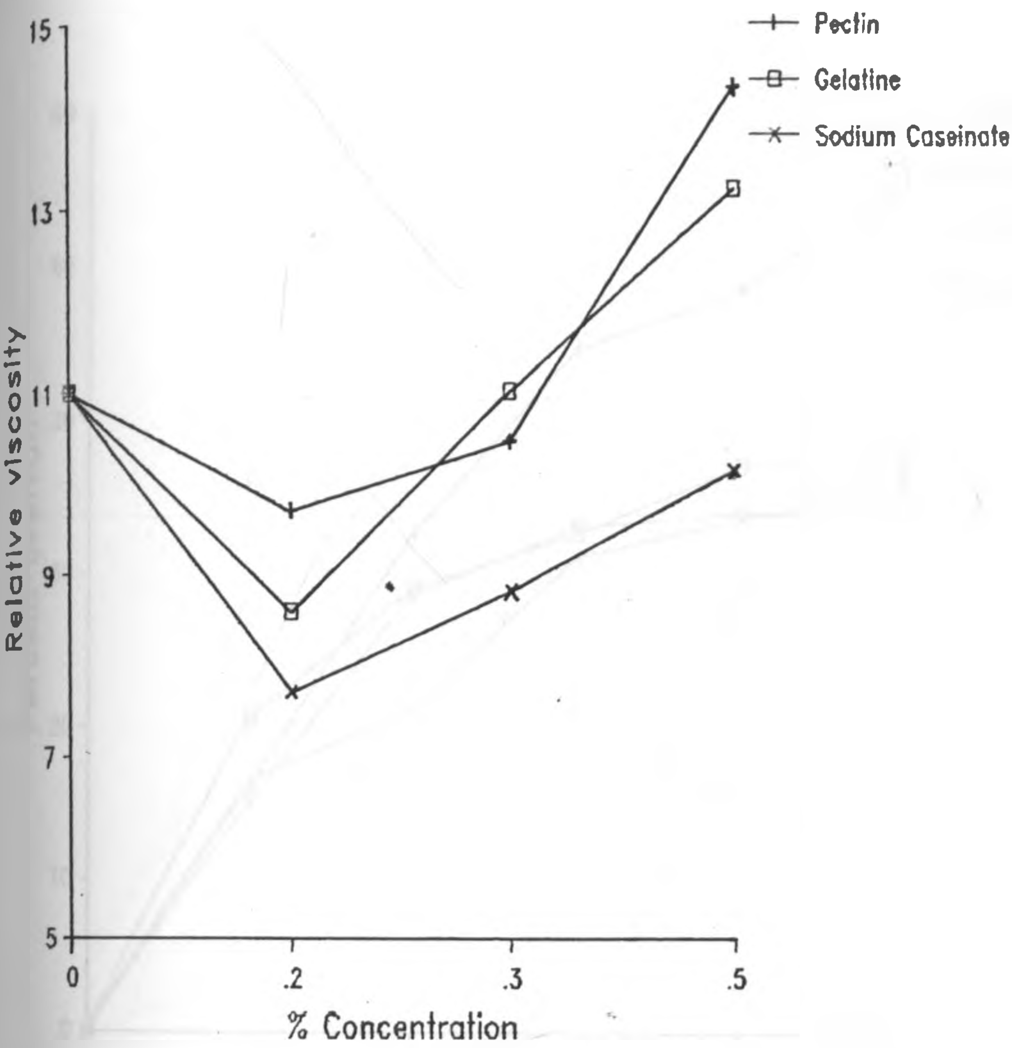

Figure 2: Effect of pectin, gelatine and sodium caseinate on relative viscosity (poise) of mix.

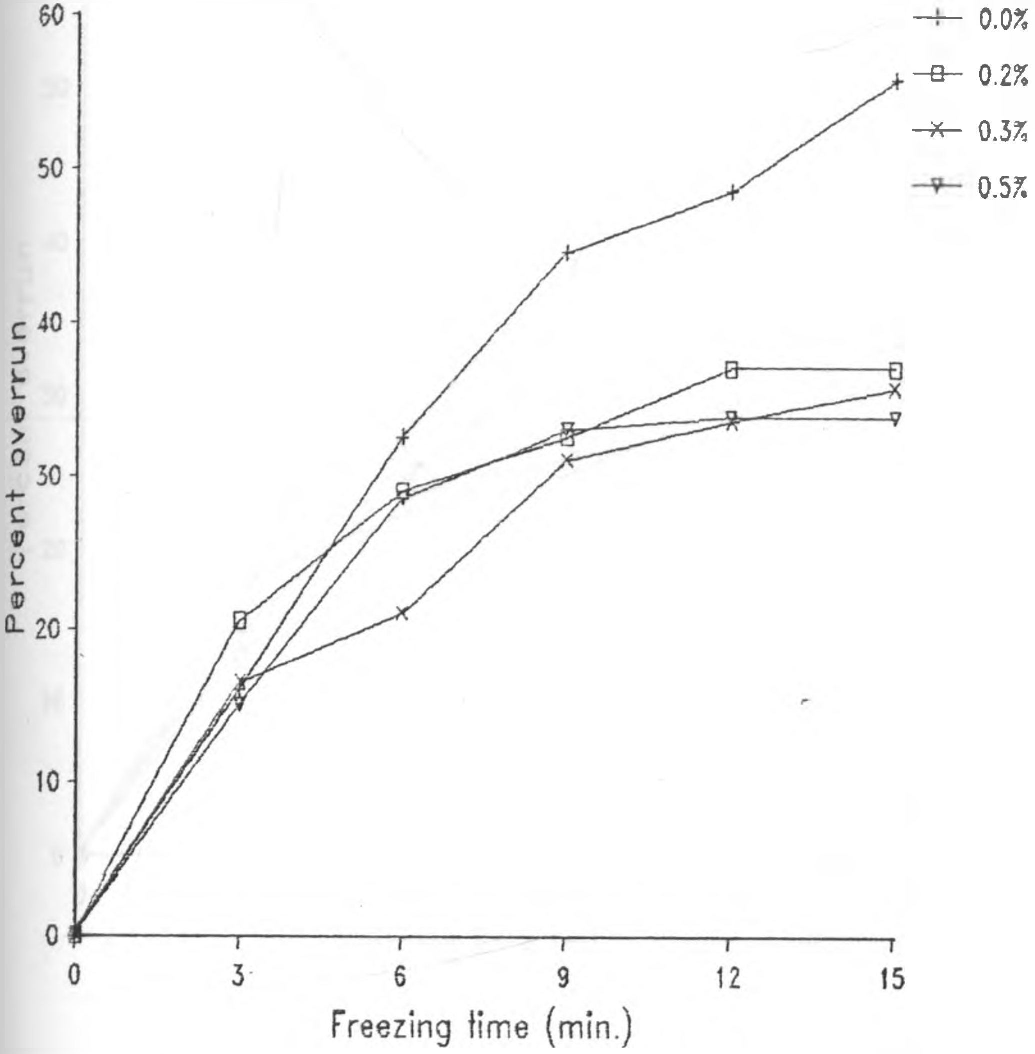

Figure 3a: Effect of whipping/freezing time on the overrun of Cultured Ice Milk containing different levels of pectin as stabilizer.

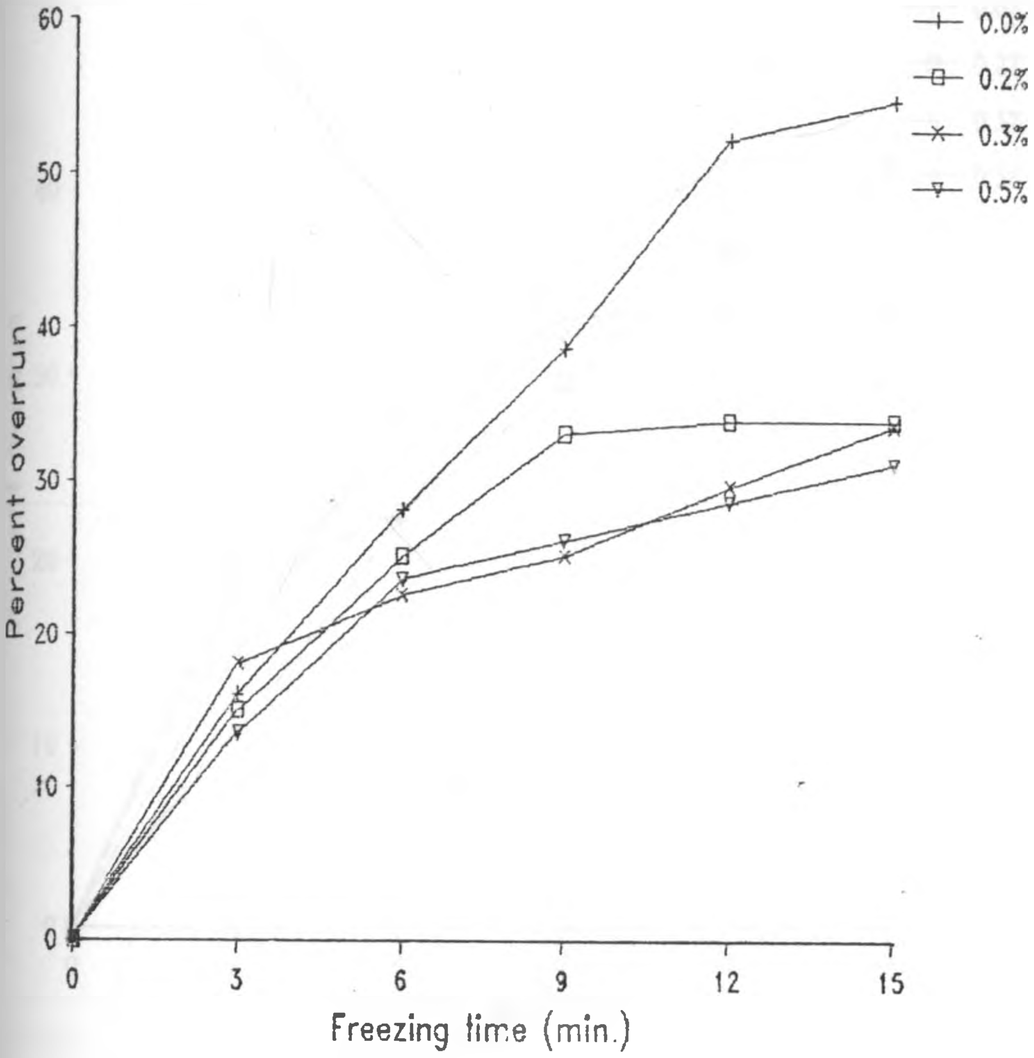

Figure 3b: Effect of whipping/freezing time on the overrun of Cultured Ice Milk containing different levels of gelatine as stabilizer.

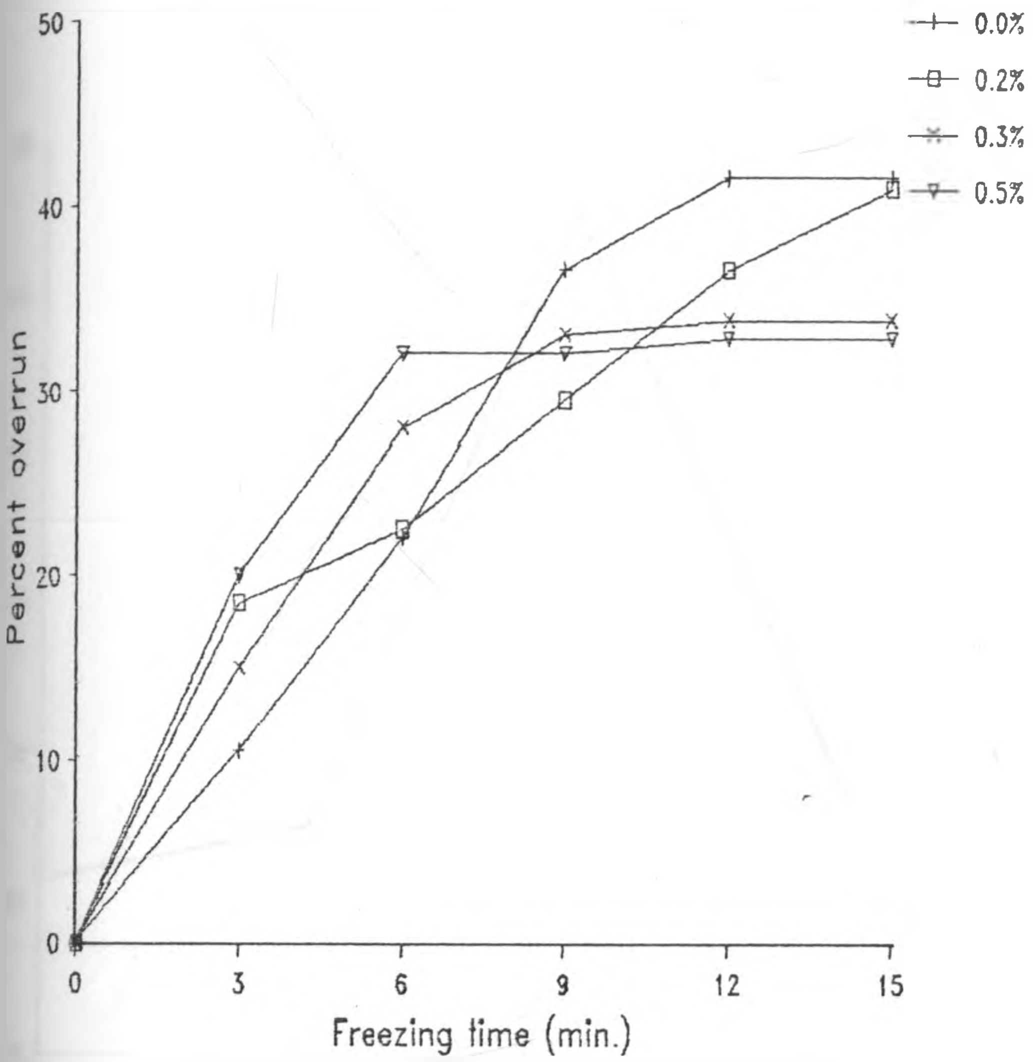

Figure 3c: Effects of Whipping/freezing time on the overrun of Cultured Ice Milk containing different levels of sodium caseinate stabilizer.

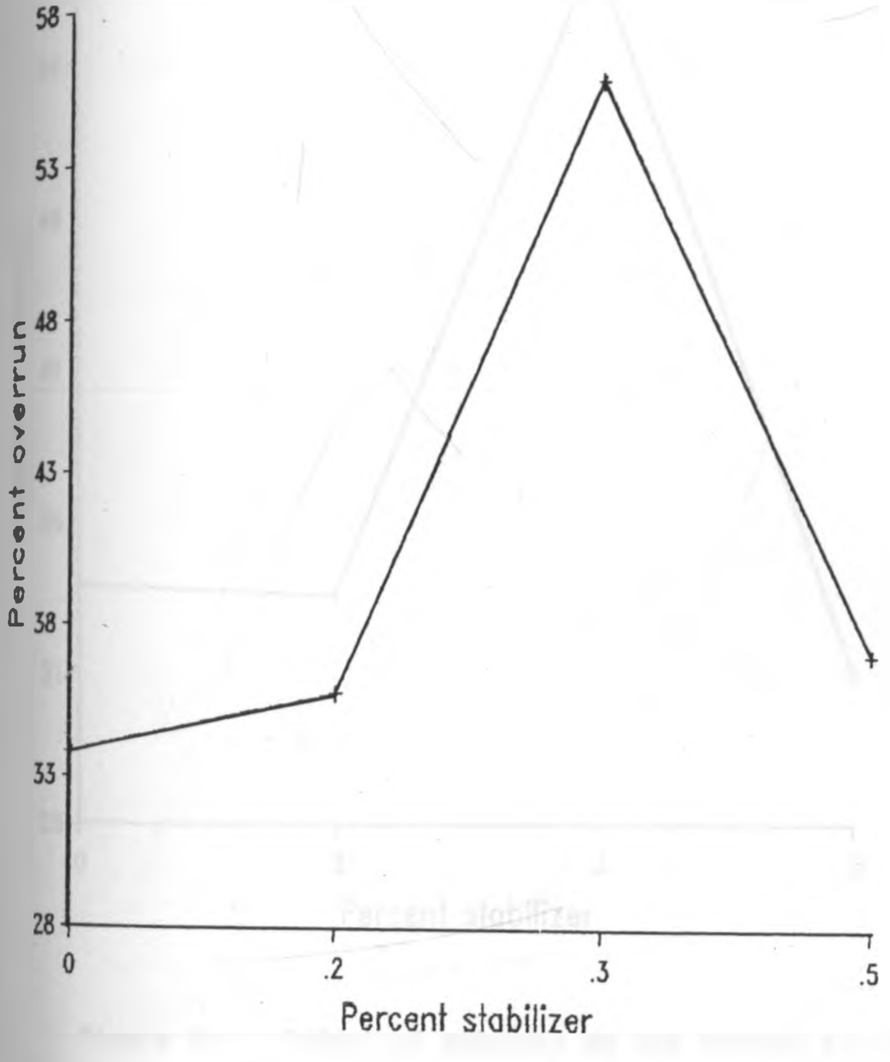

Figure 4a: Effect of pectin on the overrun (at 15 min.) of cultured ice milk mix.

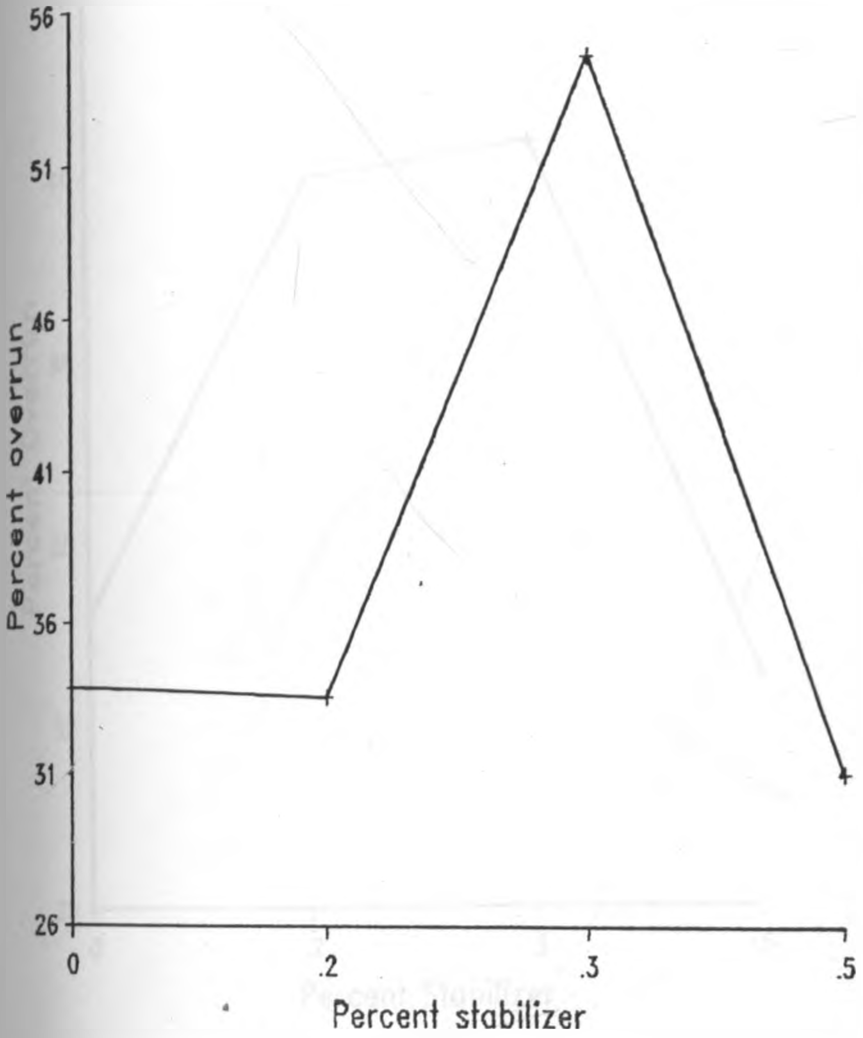

Figure 4b: Effect of gelatine on the overrun (at 15 min.) of cultured ice milk mix.

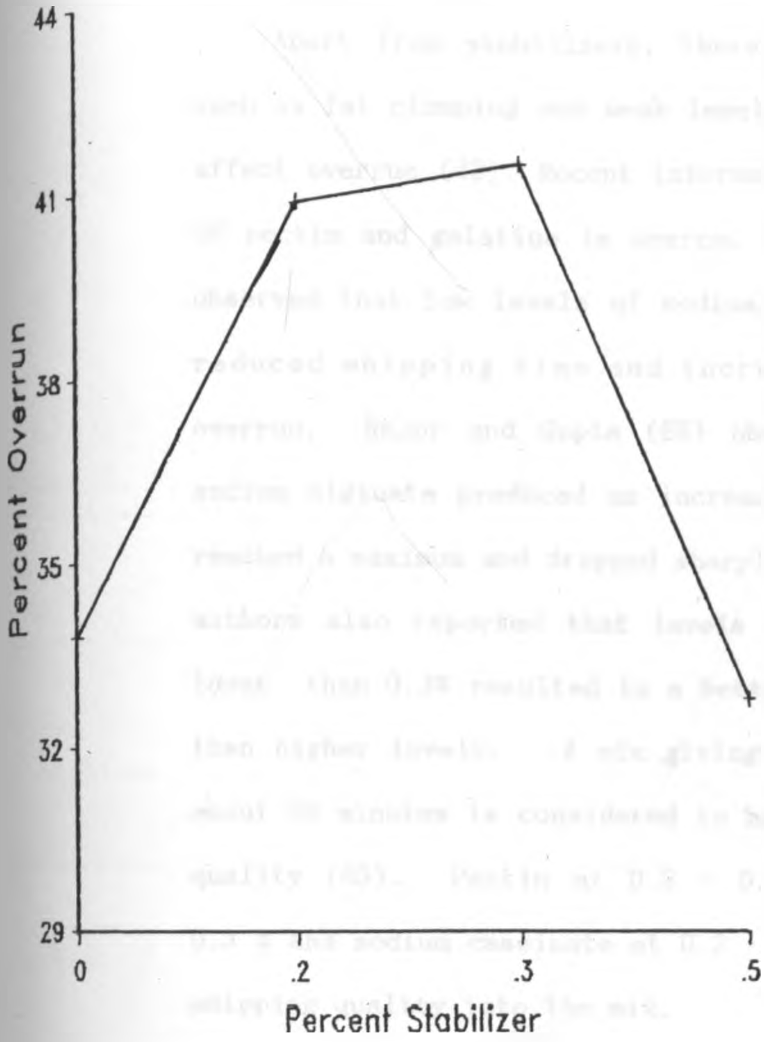

Figure 4c: Effect of sodium caseinate on the overrun (at 15 min.) of cultured ice milk mix.

Apart from stabilizers, there are other factors such as fat clumping and weak lamellae which seriously affect overrun (42). Recent information on the effects of pectin and gelatine is scarce. Bird et al. (16) observed that low levels of sodium caseinate in mixes reduced whipping time and increased the initial overrun. Rajor and Gupta (65) observed that use of sodium alginate produced an increase in overrun which reached a maximum and dropped sharply thereafter. The authors also reported that levels of sodium alginate lower than 0.3% resulted in a better whipping quality than higher levels. A mix giving 40% overrun within about 20 minutes is considered to have a good whipping quality (65). Pectin at 0.3 - 0.5% , gelatine at 0.3 % and sodium caseinate at 0.2 - 0.3% imparted good whipping quality into the mix.

The effects of pectin, gelatine and sodium caseinate on the melting rates of hardened CIM after 90 minutes ranged from 22.6% to 70.4%. Table 8 shows changes in melting rates with time. In general addition of stabilizer affected the melting rate of CIM significantly, causing it to decrease if added at levels between 0.2 - 0.3% and to increase if stabilizer levels were increased further from 0.3 to 0.5%. Pectin and gelatine caused greater resistance to melting than sodium caseinate except at 0.5% pectin.

Table 8. Effect of pectin, gelatine and sodium caseinate on the melting rate (%) of cultured ice milk

Stabilizer	Level of stabilizer (%)	Time (minutes) at 23-25 °C and the % melting rate		
		30 min	60 min	90 min
	0.0	4.7	15.4	35.5
Pectin	0.2	4.2	9.9	25.5
	0.3	2.3	9.0	20.8
	0.5	1.9	3.9	58.1
Gelatine	0.2	4.0	10.1	22.6
	0.3	3.5	10.3	19.5
	0.5	7.5	26.9	42.6
Sodium Caseinate	0.2	3.0	14.2	39.3
	0.3	3.7	13.8	37.0
	0.5	7.4	20.0	42.7

A foamy melt and whey separation was observed in CIM containing less than 0.3% stabilizer. However, at levels of stabilizers of 0.3% and above , the melt was milky without whey separation. The melting resistance tended to increase with the level of pectin and gelatine in the range of 0.2 - 0.3%. However, at 0.5% pectin and gelatine concentrations, the melting rate decreased. A decrease in melting resistance had been observed with all concentrations of sodium caseinate. At present these results cannot be conclusively explained. A similar trend has been reported in ice cream (5, 65) over a bigger concentration range. It could be due to the high viscosity of the mix, which slows the drainage of the melt.

To quantify the improvement of CIM body and texture attributed to the addition of stabilizer, the penetrometer test was performed on the hardened samples. Penetrometer values ranged between 14.0 kg/cm^2 and 23.0 kg/cm^2. High stabilizer concentrations resulted in strong-bodied products. As shown in Fig. 5, pectin and gelatine were more effective in increasing hardness than sodium caseinate. At 0.3% stabilizer levels, penetrometer values were 19.2 kg/cm^2 for pectin and 22.0 kg/cm^2 for gelatine but only 14.6 kg/cm^2 for sodium caseinate. Penetrometer values tend to be inversely proportional to overrun. Mann (54) indicated that overrun is inversely related to the penetrometer values.

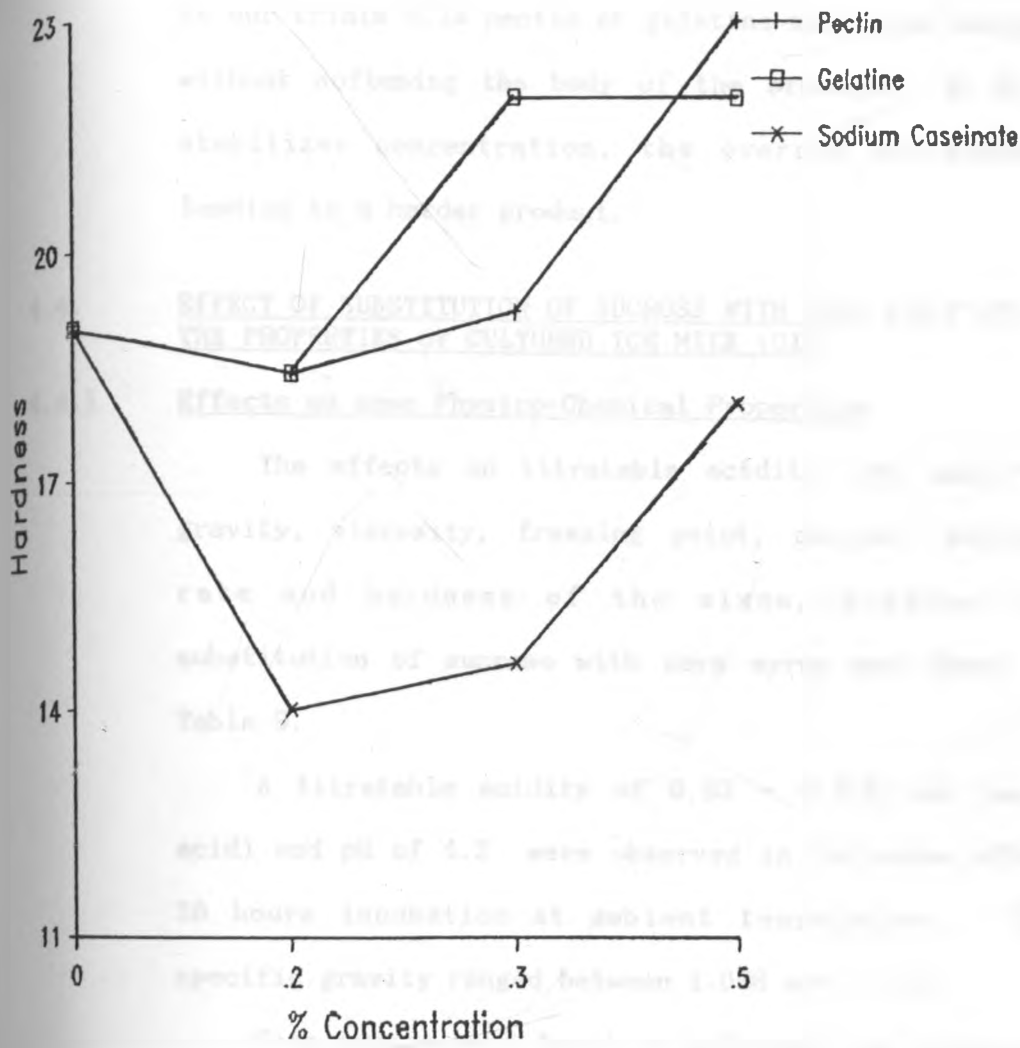

Figure 5: Effect of pectin, gelatine and sodium caseinate on hardness (kg/cm²) of cultured ice milk.

In our trials 0.3% pectin or gelatine maximized overrun without softening the body of the product. At 0.5% stabilizer concentration, the overrun decreased , leading to a harder product.

4.4. EFFECT OF SUBSTITUTION OF SUCROSE WITH CORN SYRUP ON THE PROPERTIES OF CULTURED ICE MILK (CIM)

4.4.1 Effects on some Physico-Chemical Properties

The effects on titratable acidity, pH, specific gravity, viscosity, freezing point, overrun, melting rate and hardness of the mixes, produced by substitution of sucrose with corn syrup are shown in Table 9.

A titratable acidity of 0.83 - 0.91% (as lactic acid) and pH of 4.3 were observed in the mixes after 20 hours incubation at ambient temperature. The specific gravity ranged between 1.068 and 1.143.

Corn syrups were found to influence the viscosity of CIM mix. Progressive substitution of sucrose with CS of 30.6DE generally increased the viscosity of the mix upto a substitution of 100%. However substitution with the corn syrup of 74.7DE increased the relative viscosity of the mix upto a maximum after which there was a drastic decrease as shown in Figure 6.

Figure. 7 illustrates the effect of substitution of sucrose with CS on the freezing point. As expected, increasing corn syrup substitution for sucrose in the mix resulted in a linear increase of the freezing point depression. Furthermore it was observed that for the same level of substitution, the 74.7 D.E corn syrup depressed the freezing point more than the 30.6 D.E. corn syrup.

Two different types of corn syrup were used as partial and full substitutes for sucrose. Concentration of the syrup and extent of substitution affected both viscosity and freezing point of the mixes. This is in agreement withe results from literature (78).

The viscosity of a fluid is a function of its dry matter content and the molecular sizes of the particles. The viscosity increases with increasing solids content and with the size of the solids molecules (78).

The effects of various sweeteners on the viscosity of frozen desserts have been reported by various authors. Smith et al. (78) found that glucose "structures" aqueous systems more than sucrose. Sweeteners which contain large amounts of glucose increase this "structural" difference accordingly. Corn syrups of high DE values (i.e. containing large amounts of glucose) can therefore be expected to "structure" mixes more than low DE corn syrups. A similar trend was observed at low levels (25 %) of substitution. However, at 50% and 75% substitution, 30.6 D.E. corn syrup imparted higher viscosities than 74.7 D.E. corn syrup. The 30.6 D.E. corn syrup

Table 9. Effect of progressive sucrose substitution with corn syrups on some physical properties of cultured ice milk (CIM)

	Degree of Substitution (%) with Corn syrup								
	0	25		50		75		100	
Physical property		30.6DE	74.7DE	30.6DE	74.7DE	30.6DE	74.7DE	30.6DE	74.7 DE
Specific Gravity	1.072	1.099	1.068	1.117	1.078	1.117	1.088	1.143	1.080
Viscosity (poise)[a]	14.30	13.75	16.39	16.00	13.80	18.48	10.45	--	9.80
Depression of freezing point (°C)	2.00	2.05	2.00	2.04	2.25	2.29	2.36	2.31	2.44
Overrun (%)[b]	37.0	37.0	37.0	25.1	18.3	--	--	19.6	25.2
Melting rate (%)[c]	58.1	36.8	60.9	39.6	48.0	49.5	43.2	51.0	48.9
Hardness (Kg/cm^2)[d]	23.0	24.0	23.0	6.0	8.2	12.4	12.4	18.2	17.2

Notes: [a]Measuring system C (torsion viscometer) at $24.9s^{-1}$ shear rate
[b]Freezing time = 15 min.
[c]Amount, expressed as % of CIM melted in 90 min. at 23.25 °C
[d]Force applied to penetrate 0.7cm of CIM (probe surface area = 0.5 cm^2
DE = Dextrose Equivalent
-- samples not tested due to lumps

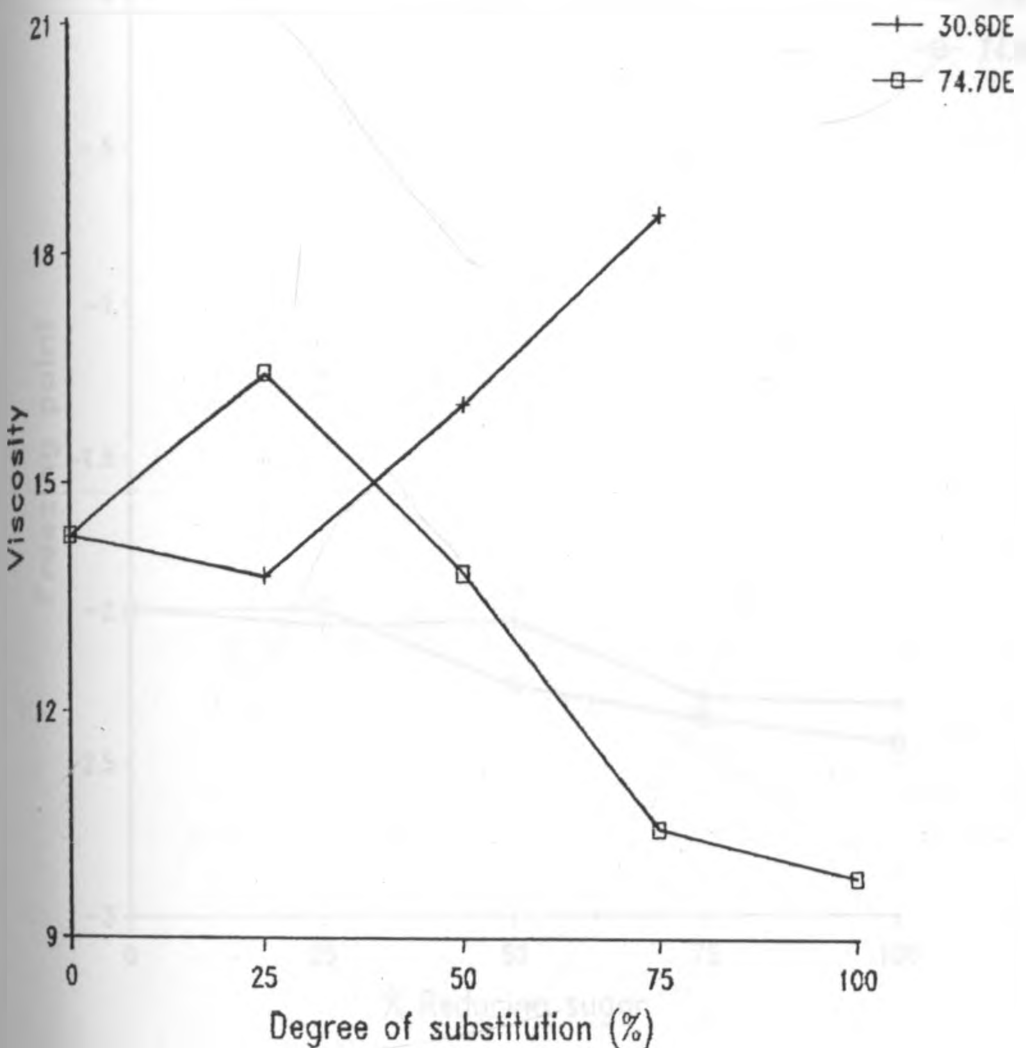

Figure 6: Changes in viscosity due to substitution of sucrose with corn syrups.

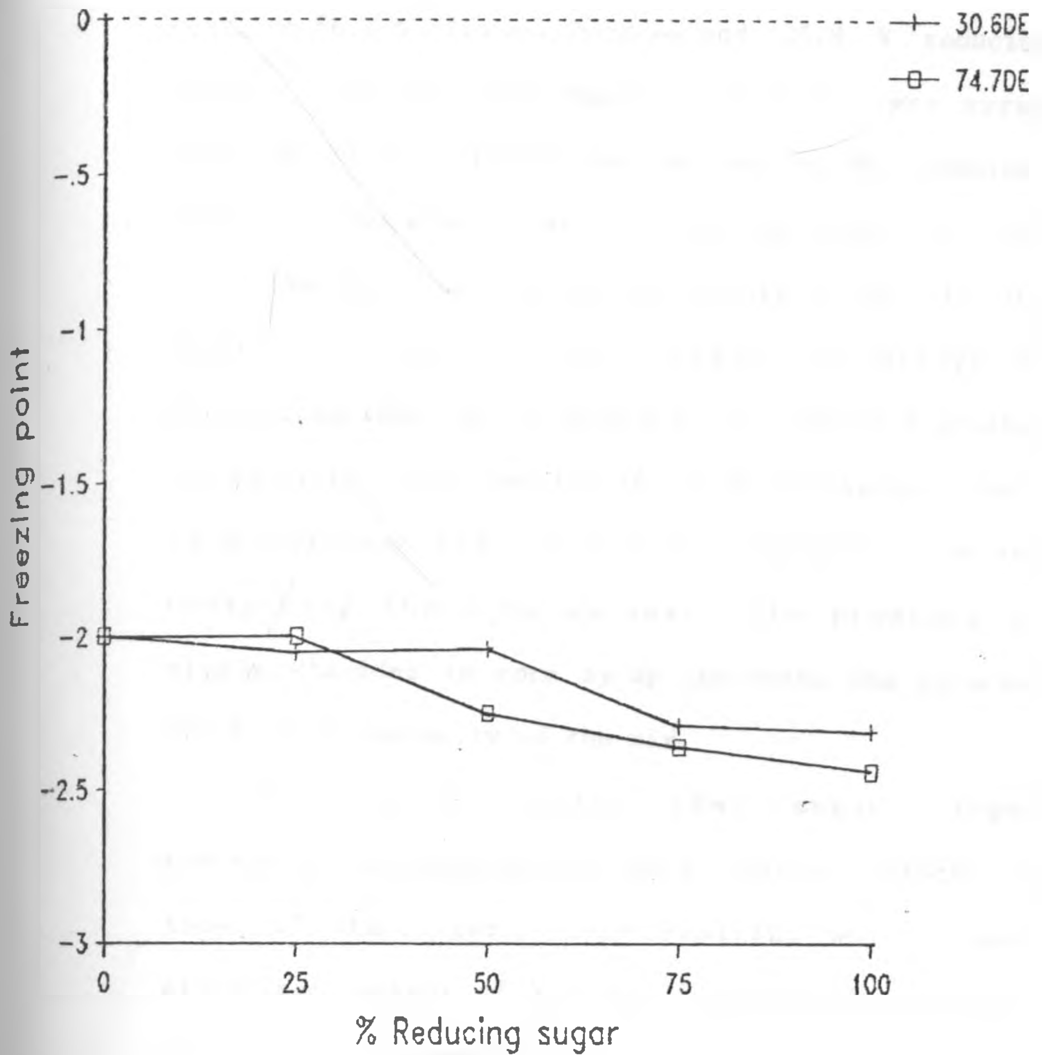

Figure 7: Effects of substitution of sucrose with corn syrups of 30.6 DE and 74.7 DE on the freezing point of Cultured Ice Milk mix.

contains 56.2 % oligosaccharides and 24.8 % reducing sugars. On the other hand, 74.7 D.E. corn syrup contains 20.2% oligosaccharides and 61.9% reducing sugars. Arbuckle (8) showed that the mono-, di- and trisaccharides in corn syrups mainly constitute the dextrose equivalent. The bigger percentage of oligosaccharides, as in 30.6 D.E. CS, causes a greater viscosity increase than the 74.7 D.E corn syrup. Table 10 summarises the dry matter contents of mixes containing the corn syrups. The presence of oligosaccharides in corn syrup increases the internal friction or viscosity of the mix.

Friberg (32) noted that sugar types containing polysaccharides have similar effects to those of stabilizers. This explains why a lower stabilizer content of 0.3% still give well stabilized products. Wittinger and Smith (91) observed stabilizer-corn syrup interaction when high levels of both components were present in the mix, thus limiting the hydration of the components. This behaviour results in reduced viscosity. Increase or decrease in viscosity is certainly influenced by the hydration of the components (77).

Freezing point depression values between 2.2 deg.C and 2.8 deg.C have been reported in ice cream mixes (42, 88). Wittinger and Smith (91) obtained a freezing point depression of 2.16 deg.C when using 50% sucrose and 50% corn syrup of 36 DE. When 50% sucrose

Table 10: Total dry matter (DM) content and viscosity of CIM mixes[a] containing different levels of sucrose and corn syrups

Corn syrup	Ratio of Sucrose to corn syrup sugars	Total dry matter	Suc : CS : Oligo	Viscosity (poise) at $24.9s^{-1}$ Speed setting II
30.6 DE	100 : 0	35.00	19.00 : 0.00 : 0.0	14.30
	75 : 25	40.00	14.25 : 4.75 : 10.8	13.75
	50 : 50	43.88	9.50 : 9.50 : 21.6	16.00
	25 : 75	47.00	4.50 : 13.50 : 30.7	18.48
	0 : 100	49.52	0.00 : 19.00 : 43.1	--
74.7 DE	100 : 0	35.00	19.00 : 0.00 : 0.0	14.30
	75 : 25	35.51	14.25 : 4.75 : 1.6	16.39
	50 : 50	36.00	9.50 : 9.50 : 3.1	13.80
	25 : 75	36.45	4.75 : 14.25 : 4.7	10.45
	0 : 100	36.88	0.00 : 19.00 : 6.2	9.80

Note: [a]Mixes with 12.0% MSNF and 19.0% sugars other than lactose

Suc = sucrose

CS = corn syrup sugars

Oligo = oligosaccharides

and 50% corn syrup of 30.6 DE CS were used a freezing point depression of 2.04 deg.C was obtained.

The freezing point of a mix depends on the content of soluble constituents (sugar and MSNF), on their molecular weight, as well as on the degree of dissociation in the event of electrolytes. It will vary accordingly with composition (8,10). In this study, type and quantity of sweeteners were expected to have a big influence on the freezing point depression.

Non-electrolytic dissolved constituents lower the freezing point in inverse proportion to their molecular weight (8,10). Glucose (MW = 180) will depress the freezing point almost twice as much as sucrose (MW= 342). The effective molecular weight is defined as the average weight of all dissolved molecules in the product (78). Accordingly, high DE corn syrups depress the freezing point of the mix more than low DE corn syrups.

Low freezing point products are more prone to heat shock and softening in home freezers than high freezing point products. On the other hand, products become too hard with many tiny ice crystals if the freezing point is too high. A softer product has a shorter shelf-life because it loses overrun faster, shrinks and the free water re-crystallizes, imparting an icy and coarse texture (10,12,19,77). Mixes exhibiting low freezing point would inevitably require lower freezer temperatures in order to maintain the desired firmness (19).

Table 11 shows that increasing proportions of corn syrup adversely affect overrun. Experiments with stabilizers described in section 4.3 when added at rates of 0.3% produced overruns of 41.5 - 55.8%. In our experiments with various proportions of sucrose and corn syrup, overruns ranging from 18.3 to 37.0% were obtained. Addition of corn syrup above the 25% level of substitution reduced the maximum overrun of 37% to less than 30%.

Increasing sugar levels in mixes decrease the whipping quality except when added after homogenisation, when it increases the whipping quality (8).

As shown in Table 12 increasing substitution of sucrose with corn syrup resulted in lower melting resistance in the short run (30 min and 60 min). The trend was the same with both corn syrups of 30.6 DE and 74.7 DE. Wittinger and Smith (91) also found that low DE corn syrup produced frozen dessert with improved meltdown. Mahdi and Bradley (52) reported that products in which 25 - 65% sucrose had been replaced with corn syrups of high maltose content had slower melting rate than products without corn syrup. Melting of a frozen dessert should be fairly slow and the melted product should have a consistency and appearance similar to that of the original mix, i.e. there should be no separation into various phases (53). A "does not melt" criticism is given when the frozen dessert retains its relative shape even after considerable exposure to room temperature. It has been stated that air in ice cream affects its thermal conductivity (12). Overrun could hence be expected to influence the melting rate. Air in the product imparts an insulating effect, reducing the speed of temperature changes. Lipsch (52) stated that high overruns (>80%) lead to foamy dry consistency and slow melting behaviour.

Replacing sucrose with corn syrup altered the body or hardness of the CIM. As illustrated in Figure 8, the CIM became softer with substitution rates higher than 25%. There was not a big difference between the effects of 30.6 DE and 74.7 DE. It was found that replacing sucrose with corn syrup decreased the yield value for hardness. Similarly, Carter et al. (19) had found that replacing sucrose with corn-derived sweeteners resulted in softer ice cream at normal freezer temperatures. The softer the frozen dessert in the freezer the shorter is its shelf-life, because it loses air or overrun faster, and as a result shows signs of shrinking away from the sides of the package. In addition, the water in the product is not held in a static state. Therefore it migrates to the ice crystals already present in the frozen dessert. These ice crystals grow larger and the product becomes coarse to taste.

Table 11: Influence of sucrose substitution with corn syrup on the whipping quality (overrun) of Cultured Ice Milk mix (standard mix).

Corn Syrup	Degree of Substitution (%)	% Overrun		
		5 min	10 min	15 min
30.6 DE	0	24.6	33.8	33.8
	25	23.0	36.0	37.0
	50	20.8	25.1	25.1
	100	11.3	19.6	19.6
74.7 DE	0	24.6	33.8	33.8
	25	31.7	37.0	37.0
	50	16.1	18.3	18.3
	100	19.3	30.7	25.2

Table 12: Influence of sucrose substitution with corn syrup on the melting rates of Cultured Ice Milk

Corn Syrup	Degree of Substitution (%)	% Melted at 23 - 25 °C		
		30 min.	60 min.	90 min.
30.6 DE	0	1.1	3.9	58.1
	25	5.1	11.1	36.8
	50	4.0	14.7	48.0
	75	5.5	15.1	49.5
	100	6.0	16.4	51.0
74.7 DE	0	1.0	3.9	58.1
	25	2.0	--	--
	50	3.1	7.1	39.6
	75	3.3	10.1	43.2
	100	6.0	23.1	48.9

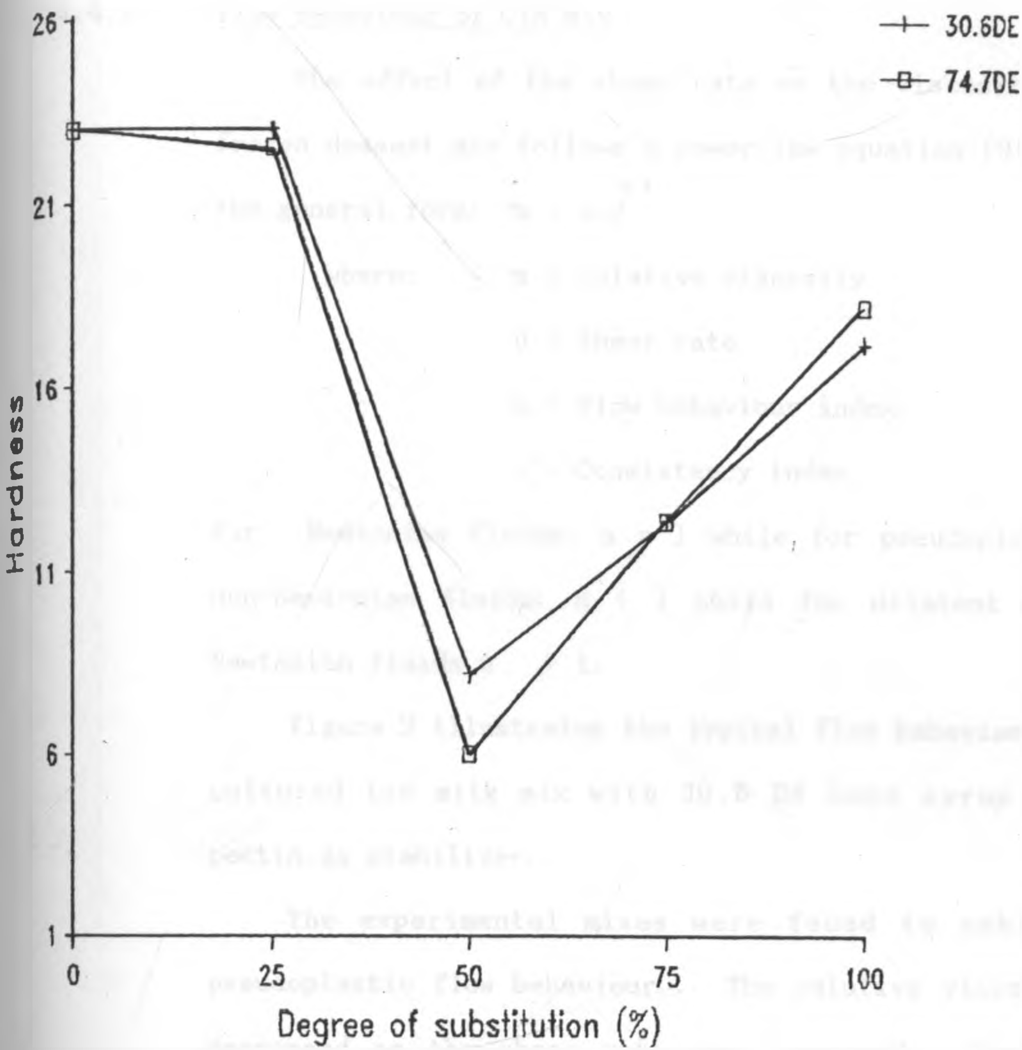

Figure 8: Changes in hardiness due to substitution of sucrose with corn syrups.

4.4.2 Flow Behaviour of CIM Mix

The effect of the shear rate on the viscosity of frozen dessert mix follows a power law equation (91) of the general form: $\eta = x.D^{n-1}$

where: η = relative viscosity

D = Shear rate

n = Flow behaviour index

x = Consistency index

For Newtonian fluids: n = 1 while for pseudoplastic non-Newtonian fluids: n < 1 while for dilatant non-Newtonian fluids n > 1.

Figure 9 illustrates the typical flow bahaviour of cultured ice milk mix with 30.6 DE corn syrup and pectin as stabilizer.

The experimental mixes were found to exhibit pseudoplastic flow behaviour . The relative viscosity decreased as the shear rate was increased. Earlier work has shown similar results in ice cream and yoghurt mixes (5, 23, 36, 78, 91).

The viscosity of a mix gives an insight into the structure of the mix (78). From Figure 9 and Table 13 it can be seen that increase in shear rate resulted in shear thinning in all the products. Shear thinning prevails when molecules in the mix e.g. stabilizers and sweeteners align themselves along the shearing gradient, resulting in reduced viscosity at any given shear rate.

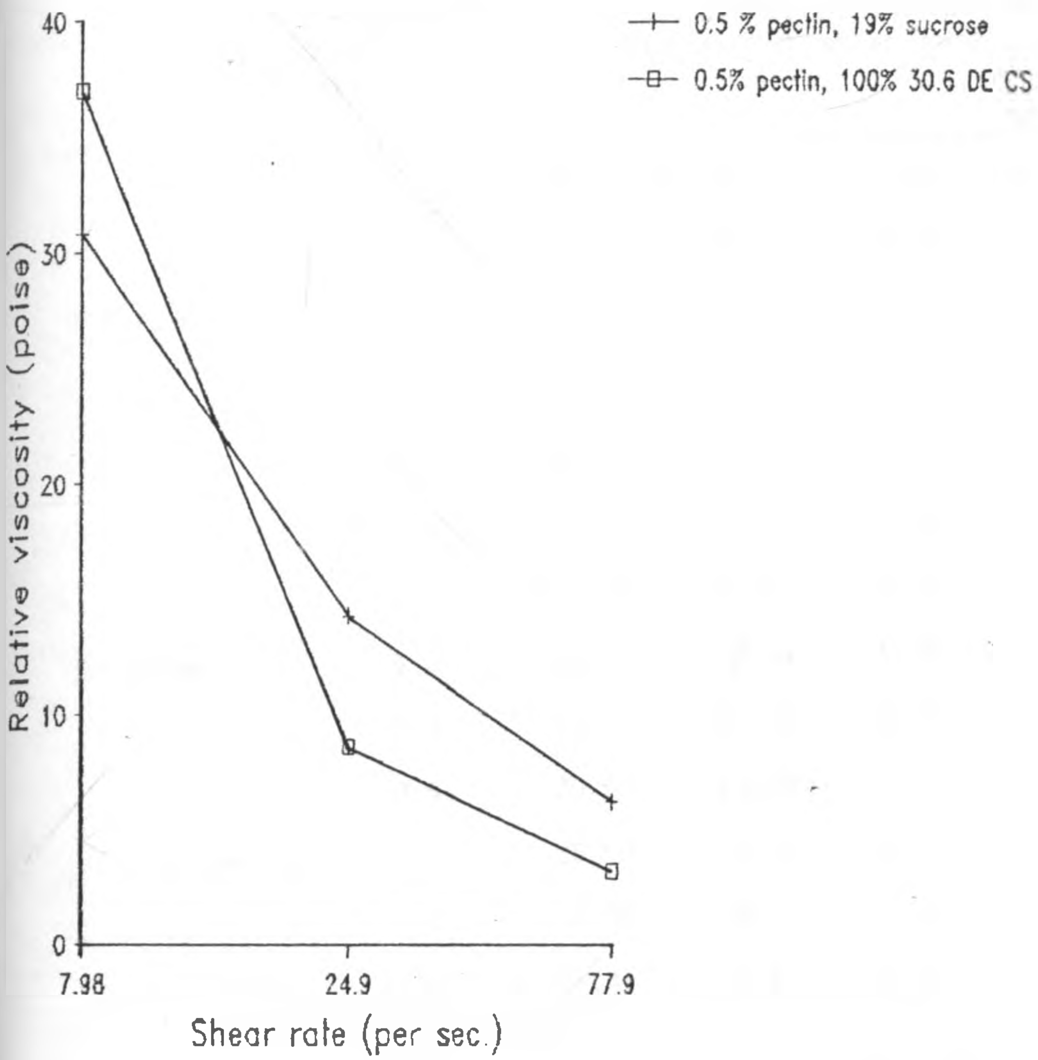

Figure 9: Flow behaviour of Cultured Ice Milk mix.

Table 13: Effect of stabilizers and sucrose substitution with corn syrup and 0.5% pectin as stabilizer on the viscosity of standard mix at 5 °C measured at shear rates of 7.98, 24.9 and 77.9 s^{-1}

		Viscosity in poise at shear rates (s^{-1})		
		7.98	24.9	77.9
Stabilizer	% Level			
	0.0	26.75	11.00	4.51
Pectin	0.2	24.00	9.68	3.73
	0.3	27.40	10.45	4.75
	0.5	37.00	14.30	6.21
Gelatine	0.2	24.70	8.58	4.29
	0.3	24.00	11.00	3.73
	0.5	20.58	13.20	3.45
Sodium caseinate	0.2	20.60	7.70	3.52
	0.3	24.70	8.80	4.22
	0.5	26.41	10.12	4.22

Corn syrup	% Sucrose substitute	Viscosity in poise at shear rates (s^{-1})		
		7.98	24.9	77.9
30.6 DE	0	37.04	14.30	6.16
	25	34.64	13.75	5.91
	50	35.00	16.01	7.20
	75	37.00	18.48	8.50
	100	30.80	---	3.20
74.7 DE	25	34.44	16.39	6.03
	50	34.10	13.80	6.00
	75	33.40	10.45	6.20
	100	32.20	9.80	4.70

4.5 SELECTION OF THE BEST STABILIZER FOR PREPARATION OF ICE MILK

The physical properties of mixes varied with the type and amount of stabilizer. Pectin, gelatine and sodium caseinate had different effects on the properties of the mixes. It was therefore necessary to select the best stabilizer for further trials.

4.5.1 Optimisation of the Physical Properties of Unflavoured Cultured Ice Milk with Stabilizers

There was a remarkable increase in the overrun of unflavoured CIM with upto 0.3% pectin, gelatine or sodium caseinate. However, addition of 0.5% stabilizer resulted in reduced overruns. Pectin and gelatine always produced higher overruns than sodium caseinate.

Addition of 0.3% pectin to the CIM is equivalent to addition of 0.3% gelatine as has already been seen in Table 7. These quantities of stabilizers result in overruns of 55.8% and 54.5% respectively. Addition of sodium caseinate only at the same level produced a maximum of 41.5% overrun. At 0.3% stabilizer concentration meltdowns of 20.8%, 19.2% and 37.0% with pectin, gelatine and sodium caseinate respectively were obtained. Although there exists no uniform definition of melt-down it is regarded as a good indicator for melting resistance.

The overruns obtained with pectin or gelatine at 0.3% level in the CIM mix is within the range recommended by Arbuckle (8) and Chandan (20) for ice milks, including frozen yoghurts. The levels of pectin and gelatine are also comparable to those suggested by several authors (24, 67, 86).

One would choose pectin or gelatine depending on cost and availability. At present, the two are widely available in Kenya. However, Wangoh (87) reported a limited use of gelatine in cultured milk products despite the fact that it has been used to improve the viscosity of cultured milks elsewhere. Pectin was chosen for the subsequent trials because of its marked improvement in overrun, good compatibility with fruits and fairly good melting characteristics.

4.6 SELECTION OF THE OPTIMUM SUCROSE/CORN SYRUP COMBINATION

Corn syrups were used to replace sucrose. The properties of the corn syrups have already been shown in Table 6. Due to the difference in their DE values, it was anticipated that the two corn syrups would elicit different effects on the sensory and physical properties of the unflavoured CIM. It therefore became necessary to select the optimal sucrose/corn syrup combination for each corn syrup for further experiments.

4.6.1 Optimisation of Sensory and Physical Properties of CIM

The effects of sucrose substitution with corn syrup on sensory scores of CIM after seven days storage are shown in Figures 10a and 10b. Generally, the mean sweetness and hardness scores of the samples containing CS of 30.6 DE were rated higher than those containing CS of 74.7 DE. However, there was no significant difference ($P < 0.01$) among the scores of the two samples when analysis of variance (ANOVA) was carried out.

Interestingly, panelists rated the 50:50 (corn syrup sugars : sucrose) ratio slightly sweeter than 100% sucrose in the CIM. The panelists also awarded this level of substitution slightly higher preference scores of 5.9 and 5.3 for mixes containing CS of 30.6 DE and 74.7 DE respectively. However, the scores of the products containing CS of 30.6 DE and CS of 74.7 DE respectively, at both 50% and 100% level of substitution were not significantly different ($P < 0.01$). Preference scores on sweetness were higher at 50% level of substitution compared to 0% substitution and 100% substitution for both corn syrups.

Substitution of sucrose with CS at 50% substitution improved the sweetness scores over the 0.0% and 100.0% substitution. However, the scores for hardness of the products containing corn syrup were lower than the scores for products containing only sucrose.

Previous trials (Table 9) had shown that at 50% level of substitution, the overrun was adversely affected, being reduced to less than 30%. Because of the superior physical and sensory properties of the products, 25% level of substitution with 30.6 DE CS was selected for all subsequent studies. This level of substitution is comparable to that reported by Arbuckle (8), who stated that 25 - 35% of total sugars can be supplied by corn syrups. Dziedzic and Kearsley (27) also recommended 25% level of substitution with 26 - 90 DE corn syrup.

At the 25% level of substitution, 30.6 DE CS produced 37% overrun with acceptable melting resistance of the product. In addition, these products were awarded higher preference scores than those containing 25% corn syrup sugars of 74.7 DE. There were also no objectionable comments regarding the body of the ice milk.

4.7 OPTIMISATION OF FRUIT FLAVOURS IN CULTURED ICE MILK

The pH, acidity, Brix value and viscosity of the fruit preparations used are shown in Table 14. These figures are within the limits of those indicated in the literature (87). To enhance flavour in CIM, fruit-sugar mixes were prepared prior to addition as recommended by Arbuckle (8). The added sugar was accounted for in the final mix composition.

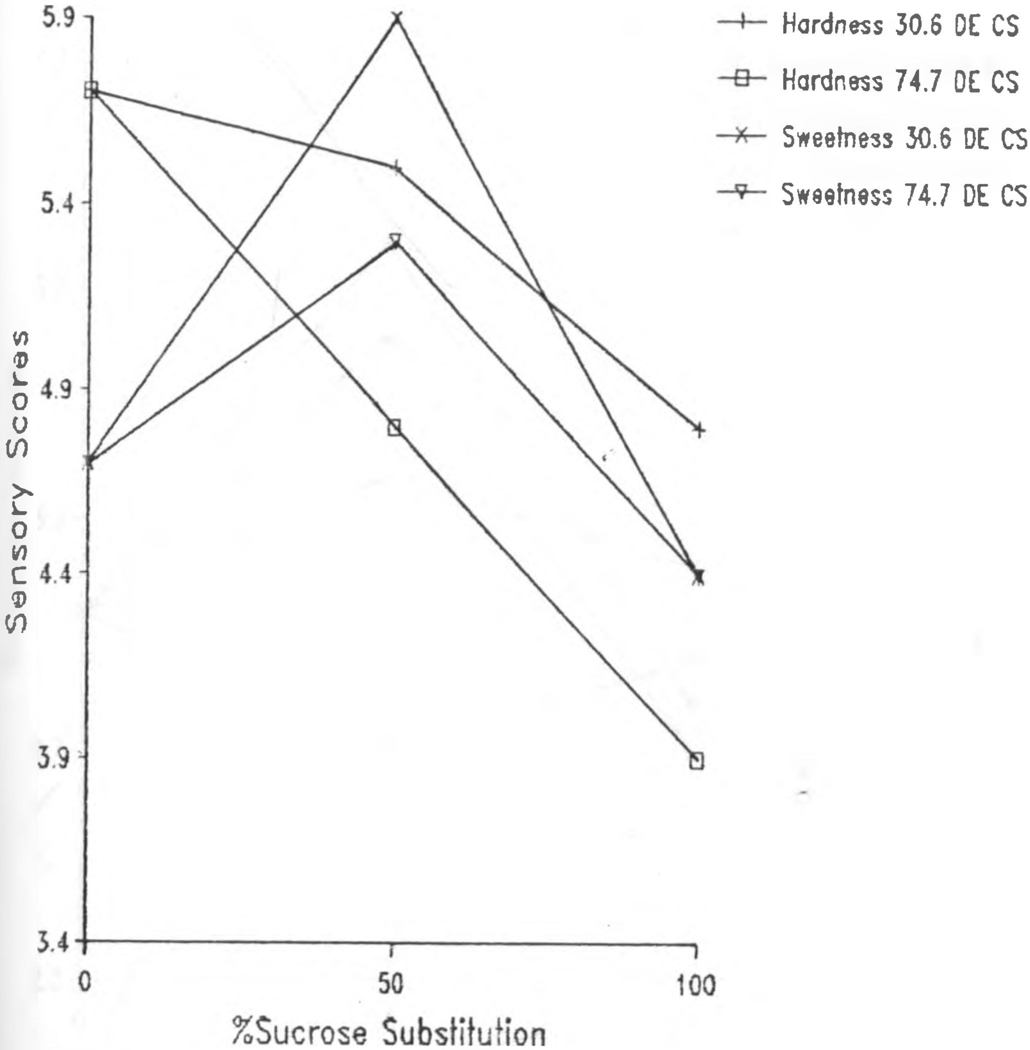

Figure 10a: Effect of sucrose substitution with corn syrup of 30.6 DE and 74.7 DE on the preference scores for hardness and sweetness of Cultured Ice Milk after one week of storage at -15°C.

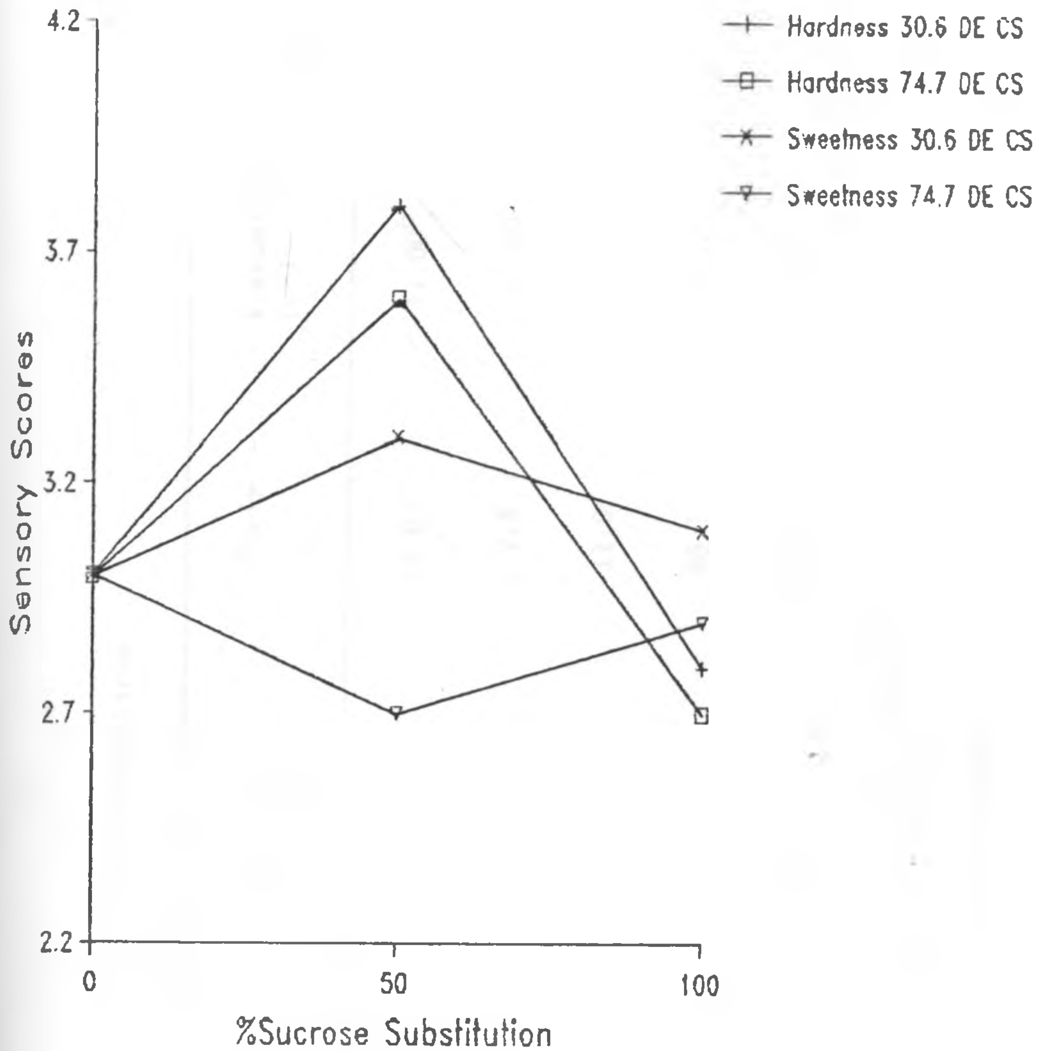

Figure 10b: Effect of sucrose substitution with corn syrup of 30.6 DE and 74.7 DE on the intensity scores for hardness and sweetness of Cultured Ice Milk after one week at -15°C.

Table 14: Physico-chemical properties of the fruit preparations

Fruit preparation	pH	Acidity as citric acid (%)	°Brix	Viscosity[a] (cP)
Mango pulp	4.4	1.27	14.0	11.00[b]
Strawberry pulp	3.6	1.73	7.5	15.40
Lemon juice	2.2	--	11.0	--
Passion fruit concentrate	2.6	4.47	45.1	12.65
Pineapple concentrate	3.2	0.71	60.0	38.50

[a]Measured at $5^{\circ}C$, with system C and speed setting II

[b]Speed setting III used

4.7.1 Optimisation of Fruit Flavour Levels

The sensory scores of cultured ice milk flavoured with different fruit levels are shown in Table 15. The fruit levels tested for each fruit covered the optimum range reported for fruit flavoured Mala (87). Based on analysis of variance, the results indicate no significant differences ($P < 0.01$), in colour, odour and taste for all the products containing the three levels of fruit flavours. However, the total sensory scores were significantly different ($P < 0.01$).

Considering total sensory scores, cultured ice milk with 20% mango pulp was more acceptable than that flavoured with 16% or 18% pulp. This level was rated highest on colour, odour and taste and subsequently among all mango total flavour scores.

Cultured ice milk flavoured with 20% strawberry pulp was more liked than that with 18 or 22% pulp. Odour and taste also were most acceptable at the 20% level. However, the colour scores were equal at all the concentrations used. The product flavoured with 18% lemon juice was more acceptable than that flavoured with 14% or 16% juice. Unexpectedly, the panelists accorded the most intensive lemon colour a particularly high score. This caused the total sensory score to rise above that of 14% and 16%.

The product containing 4% passion fruit concentrate was more liked than those containing 2% or 6% passion fruit concentrate. This level was also rated highest on taste and had the highest total scores. In cultured ice milk flavoured with pineapple concentrate, levels of 6% yielded the product with the highest total scores. These products were also rated highest in both odour and taste and were alloted a relatively high score in colour.

4.7.2 Selection of the Best Fruit Flavour for Cultured Ice Milk

The results of sensory evaluation of CIM flavoured with optimum fruit levels are presented in Table 16. Based on maximum sensory scores, cultured ice milk flavoured with mango pulp had the most acceptable colour. In addition the taste was desirable and four out of the twelve panelists reported that the taste was typical of the fruit used. Mango flavoured cultured ice milk had an acceptable body and a smooth texture.

The product flavoured with strawberry pulp was considered undesirable in colour by eight out of the 12 panelists due to seed particles. Three out of 12 panelists judged the taste of CIM flavoured with strawberry pulp as empty or weak, while another three out of 12 judged the product as coarse and icy.

Table 15: Sensory scores for cultured ice milk flavoured with different fruit preparation at different levels[a]

Fruit preparation	Level of flavouring	scores for sensory attributes			Total scores for all attributes
		Colour	Odour	Taste	
Mango pulp :	16%	78	62	65	205
	18%	78	60	69	207
	20%	78	62	73	213
Strawberry pulp :	18%	62	66	71	199
	20%	64	65	73	202
	22%	64	64	69	200
Lemon juice :	14%	61	58	57	126
	16%	66	53	57	176
	18%	74	59	50	183
Passion fruit concentrate :	2%	65	65	67	197
	4%	71	63	68	202
	6%	76	66	62	201
Pineapple concentrate :	2%	73	58	61	192
	4%	70	62	58	190
	6%	72	64	64	200

[a]Maximum score = 84, Maximum total score = 252.

Five of the 12 panelists considered lemon flavoured CIM as having inadequate colour. All the 12 panelists down-graded its taste due to excess sourness. Three out of the 12 panelists criticised the lemon flavoured product for having a weak body. Four out of the 12 panelists described the CIM flavoured with passion concentrate as unattractive and having excess colour. Also, two of the panelists described the product as too sour, while three out of 12 described the product as weak-bodied.

All panelists indicated that the CIM flavoured with pineapple concentrate had the most desirable colour and melting quality when compared to the other fruit flavoured cultured ice milks. Furthermore, the product was rated best in taste, body and texture.

Twelve semi-trained panelists were used to evaluate the products. Amerine et al. (2) suggested use of 8 - 25 semi-trained panelists while Kurwijila (50) used 8 - 10 untrained panelists in the assessment of cultured milk. Lipsch (52) reported use of trained and untrained panelists in ice cream preference tests. According to Arbuckle (8) flavour scores (taste and odour) are relatively more important than colour in ice cream sensory evaluation.

Table 16: Sensory scores of Cultured Ice Milk flavoured with fruits at optimum levels[a]

Fruit Preparation	% added	scores of sensory attributes				Total scores
		Colour	Taste	Body + Texture	Melting	
Mango pulp	20	76	66	66	50	258
Strawberry pulp	20	46	59	53	56	214
Lemon juice	18	65	41	59	66	231
Passion fruit concentrate	4	69	65	63	50	247
Pineapple concentrate	6	71	70	68	58	267

[a] Maximum Score = 7 x 12 panelists = 84

In Table 17, the scores are presented according to the evaluation procedures for ice cream by Arbuckle (8). No adjustment was been made for either the microbiological quality or for tropical/sub-tropical conditions. From these figures pineapple concentrate and mango pulp were found to be the best fruit flavours for CIM in that order, followed by passion fruit concentrate, strawberry pulp and lastly lemon juice.

The optimal fruit level in cultured ice milk was 20% for mango and strawberry pulp, 18% for lemon juice, 4% for passion fruit concentrate and 6% for pineapple concentrate. Other authors have reported similar results for different fruit flavours in frozen desserts and cultured milks (8, 87).

Quantities of fruit preparation to be added to cultured milk products also generally differ among regions (87). Results showed that CIM flavoured with different preparations were not equally acceptable. Similar findings were reported for frozen and sundae-type yoghurts (38).

Since frozen desserts are eaten cold, their flavour perception is reduced when compared to products eaten at room temperature. Cultured ice milk would therefore be expected to demand more fruit flavour than cultured milk. When incorporating fruit preparations into cultured ice milks, the composition of the flavours influences the acceptability of the products

Table 17: Sensory scores of Cultured ice milk flavoured with fruits at optimum levels[a]

	scores of sensory attributes				
	Flavour (Taste + odour) (45)	Body and Texture (30)	Melting (5)	Colour (5)	Total scores (85)
Mango pulp	35.4	23.6	3.0	4.5	66.5
Strawberry pulp	31.6	18.9	3.3	2.7	56.5
Lemon juice	22.0	21.1	3.9	3.9	50.9
Passion fruit concentrate	34.8	22.5	3.0	4.1	64.4
Pineapple concentrate	37.5	24.3	3.5	4.2	69.5

[a] Based on the score card for ice cream by Arbuckle (8)
Numbers in parenthesis represent maximum scores

as was demonstrated by the rejection of lemon flavoured ice milk due to high acidity. At the same time, the preferences of the target consumer may necessitate an adjustment of the sugar/acid ratio of the original mix, intensity of flavour and colour of the fruit preparation.

5. CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that flavouring of cultured ice milk with local fruits is a real possibility to extend the range of frozen milk products.

As shown, corn syrup can successfully replace part of the sucrose requirement. It however increases the solids content of the cultured ice milk. Use of CS improves the viscosity of the mix and the sweetness and body of the ice milk but adversely affects the overrun if used at a rate of 50% or more. Sucrose substitution was optimal at 25%. Corn syrup of 30.6 DE was found superior to corn syrup of 74.7 DE with respect to overrun and hardness of the ice milk.

Additional work may be needed to optimise the levels of fruit flavours over a wide range and also the sugar/acid ratio in the event of lemon juice. At the same time, further study on the influence of high corn syrup concentrations on viscosity and overrun would be necessary. In certain cases, it can be recommended that weak natural flavours of local fruit (for instance strawberry) be supplemented by synthetic essences and/or synthetic food colouring (strawberry, lemon, passion fruit). By the same it is suggested that use of natural food colouring essences (beetroot, mulberry, anatto, etc) grown in

Kenya be assessed. It might also be necessary to investigate the possibility of incorporation of other fruit flavours like banana, guava, etc.

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APPENDIX I: ICE MALA HEDONIC SCORING

Date ____________________

Name _____________________

You will receive, in random order, samples of Mala ice. Taste and evaluate for Sweetness and Hardness (firmness) applying the given intensity scale.

INTENSITY SCALE

1 - Very weak

2 - Weak

3 - Medium

4 - Strong

5 - Very strong

SAMPLE CODE	SWEETNESS	HARDNESS
_________	___________	___________
_________	___________	___________
_________	___________	___________
_________	___________	___________

Also evaluate each of the samples for the following attributes: (a) Sweetness and (b) Hardness scoring on the following scale:

Score		Description
7	-	Like very much
6	-	Like moderately
5	-	Like slightly
4	-	Neither like nor dislike
3	-	Dislike slightly
2	-	Dislike moderately
1	-	Dislike very much

SAMPLE CODE	SWEETNESS SCORE	HARDNESS SCORE
--------	------------	-------------
--------	------------	-------------
--------	------------	-------------
--------	------------	-------------

Do you like the products ? Yes/No

Remarks: ....

....

APPENDIX II: FRUIT FLAVOURED, CULTURED ICE MILK

Name ....

Date ....

You will receive, in random order, samples of cultured ice milk.

Please evaluate each sample for the following quality attributes (one attribute at a time for all the samples) applying the following scale:

Attribute: a) Colour

b) Taste

c) Smell

Scale:	Score		Description
	7	-	Like very much
	6	-	Like moderately
	5	-	Like slightly
	4	-	Neither like nor dislike
	3	-	Dislike slightly
	2	-	Dislike moderately
	1	-	Dislike very much

SAMPLE CODE	COLOUR	TASTE	SMELL
---------	------------	--------	------------
---------	------------	--------	------------
---------	------------	--------	------------
---------	------------	--------	------------

Remarks: ....

APPENDIX III: FRUIT FLAVOURED ICE MALA

HEDONIC SCORING

Date: ....

Name: ....

Please evaluate each sample for the following quality attributes (one attribute at a time for all samples): a) taste b) body and texture c) melting and d) colour, according to the following scale:

7 - Like very much

6 - Like moderately

5 - Like slightly

4 - Neither like nor dislike

3 - Dislike slightly

2 - Dislike moderately

1 - Dislike very much

You are asked to say about each sample how much you like or dislike each of the listed quality attributes. Write the code number of the sample and the number that corresponds to the phrase that best describes your assessment of the attribute. Give reasons (remarks) with aid of guide expressions below why you like or dislike an attribute. Observe sample to evaluate for melting.

Keep in mind you are the judge. You are the only one who can tell what you like or dislike and why you dislike. Nobody knows whether these products be considered good, bad, or indifferent.

An honest expression of your assessment will help us decide.

I) TASTE SCORE CARD

SAMPLE CODE	NUMBER GIVEN	REMARKS

Descriptive phrases: TASTE

Desirable attributes	Undesirable attributes
- typical of fruit used	- untypical of fruit used
- mild to slight sourish	- over sour
- full and pleasant	- empty or weak taste
- balanced sweetness	- too sweet
	- little sweetened

II) BODY AND TEXTURE SCORE CARD

SAMPLE CODE	NUMBER GIVEN	REMARKS

Descriptive phrases: BODY AND TEXTURE

Desirable Attributes	Undesirable Attributes
- ideal, balanced body	- too heavy body
- creamy product	- too weak body
- smooth texture	- coarse, icy texture

III) MELTING QUALITY SCORE CARD

SAMPLE CODE	NUMBER GIVEN	REMARKS

Descriptive phrases: MELTING

Desirable attributes	Undesirable attributes
- fairly rapid melting	- too slow melting
- uniform melt	- whey leakage
	- foamy meltdown
	- scum-like surface on melt, i.e. 'curdy' meltdown

IV COLOUR SCORE CARD

SAMPLE CODE	NUMBER GIVEN	REMARKS

Descriptive phrases: COLOUR

Desirable attributes

- uniform
- natural, typical of fruit used

Undesirable attributes

- uneven colour
- unnatural, untypical of fruit used
- excessive colour
- inadequate colour.