PROCESS DEVELOPMENT FOR THE MANUFACTURING OF INSTSNT KULFI MIX POWDER

THESIS SUBMITTED TO THE
NATIONAL DAIRY RESEARCH INSTUTE, KARNAL
IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE OF
DOCTER OF PHILOSOPHY
IN
DARING (DAIRY TECHMOLOGY)

BY
JAYANTA GHOSH

DIVISION OF DAIRY TECHONOLOGY
NATIONAL DAIRY RESEARCH INSTITUTE
(I. C. A. R)
KARNAL132001(HARYANA). INDIA
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To my beloved parents
who have always encouraged me
in my personal and academic
endeavours

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CERTIFICATE

This is to certify that the thesis entitled "PROCESS DEVELOPMENT FOR THE MANUFACTURE OF INSTANT KULFI MIX POWDER" submitted by Mr. JAYANTA GHOSH in partial fulfilment of the requirement for the award of DOCTOR OF PHILOSOPHY in Dairying (Dairy Technology) of the National Dairy Research Institute (Deemed University), Karnal (Haryana), India, is a bonafide research work carried out by him under my supervision and guidance and no part of the thesis has been submitted for any other degree or diploma.

Date 16 Sept. 1991

(G.S. RAJORHIA)
Major Advisor & Chairman (Guide)

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LIST OF ABBREVIATIONS USED

Anon	-	Annonymous
ANOVA	-	Analysis of variance
APHA	-	American Public Health Association
a_w	-	Water activity
BHA	-	Butylated hydroxy anisole
°C	-	Degree celsius
cfu	-	Colony forming unit
cm	-	Centimeter
CO_2	-	Carbon dioxide
cP	-	Centipoise
df	-	Degrees of freedom
dia	-	Diameter
DSA	-	Dairy Science Abstract
Fig	-	Figure
FFA	-	Free fatty acid
FSTA	-	Food Science and Technology Abstract
ft	-	Feet
g	-	Gram
HMF	-	Hydroxy methyl furfural
hr	-	Hour
IS	-	Indian Standards
ISI	-	Indian Standards Institute
kg	-	Kilogram
LA	-	Lactic acid
Lit	-	Litre
Ltd	-	Limited
M	-	Molar
m^2	-	Metre square
mA	-	Milli ampere
Max	-	Maximum
m eq	-	Milli equivalent
min	-	Minute
Min	-	Minimum
ml	-	Millilitre

contd.....

mm	-	Millimeter
MPa	-	Mega Pascal
mu	-	Milli micron
N	-	Normal
NA	-	Not available
nm	-	Nanometre
O_2	-	Oxygen
p-DMAB	-	Para di-methyl amino benzaldehyde
PFA	-	Prevention of Food Adulteration
RH	-	Relative humidity
Rs	-	Rupees
Sec	-	Second
SMP	-	Skim milk powder
SNF	-	Solids-not-fat
TA	-	Titratable acidity
TS	-	Total solids
TVC	-	Total viable count
u	-	Micron
ug	-	Microgram
ul	-	Microlitre
um	-	Micrometre
umoles	-	Micromoles
WMP	-	Whole milk powder

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

Kulfi is a traditional frozen milk product of India. The distinctive nutritional image contributed by high milk solids and characteristic cooked flavour make kulfi a very popular milk product. Indigenous kulfi making practice heavily relies on the use of open pan concentrated milk or khoa as a base material. The simplicity of traditional technology enables the production of kulfi at low cost and makes it available to common masses at affordable prices. The use of simple equipment, locally manageable ingredients, low grade energy sources and simple process flow encourage the manufacture of kulfi on a small scale for local marketing.

The processing of milk for kulfi making is carried out in small lots under unhygienic conditions resulting in poor microbiological quality. Because of its delectable sensory characteristics and low cost of production, kulfi, despite its widely fluctuating chemical and sensory qualities competes favourably with ice cream. The milk prices during the summer months get increased substantially. Interestingly, the demand for increasing quantity of kulfi in the summer builds up to a great extent leading to escalation of prices.

Conservation of milk solids by drying has shown an amazing upward trend in recent time owing to the extended shelf life and cost benefits the process offers in packaging, transportation and storage of dried products. Milk drying has become an integral part of the long chain between the milk producers and the consumers. Attempts have continuously been made to prepare dried milk products which upon reconstitution would resemble the native product, in terms of both sensory and nutritional properties. Numerous innovations have been made in

dried milk products with the prime objective of satisfying the consumers' convenience. Malted milk food, cheese powder, khoa powder and dried ice cream mix are some of the examples of this phenomenon. In recent years, the success of dried malted milk food and ice cream mix has helped the dairy industry to achieve significant economic benefits.

Notable advances have also been made in the development of ready-to-reconstitute convenience foods. Although processes for the manufacture of ice cream mix powder are fairly standardized, no effort has so far been made to develop technology for commercial production of kulfi mix powder. Advances in spray drying have facilitated handling of wide range of milk products designed to meet the specific needs of the consumers. It is envisaged that the existing unit processes can be adopted with certain modifications for industrial manufacture of kulfi mix powder in continuous and hygienic manner. A part of the surplus milk available can be diverted towards the manufacture of instant kulfi mix, in the dairy factories where condensing and spray drying facilities are available. The new technology will encourage product diversification in dairy plants and offer partial solution to the problem of regional and seasonal imbalances in milk supplies. New production units for kulfi mix can be established in areas where milk is found in abundance.

Packaging plays a vital role in the modern mass production of food products and their marketing. New innovations in packaging technology are proving great boon to dairy industry. Use of modern packaging techniques would certainly extend the shelf life of kulfi mix powder. The product packed in a protective packaging material with a reasonable shelf life will have a high demand at the city kulfi manufacturing centres and at homes for instant use. The extended shelf life of kulfi mix powder will exert profound influence on product acceptability, commercial viability and product's promotional value.

Instant kulfi mix powder would also offer the potential for export to Asian and African countries, especially those situated in the Middle East and South-East Asian region.

The present study was conceptualized with a view to develop the formula and technology for production of spray dried kulfi mix powder which, on reconstituion, would have the characteristic flavour and texture comparable with that of traditional product. The technology is expected to find wide acceptance amongst the dairy plants of India. The studies on cost of production and consumer acceptability would prove the commercial viability. The present investigation is the culmination of the above stated objectives for developing a suitable technology for production of kulfi mix powder with uniform composition and long shelf life.

CHAPTER 2

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Kulfi occupies a privileged position amongst the traditional Indian dairy products. Notwithstanding modernization of Indian dairying, manufacture of kulfi has largely been confined to the unorganised sector of dairy industry. Whereas, the technology for the manufacture of other milk products is fairly standardized, the published literature on this product is very scanty. In view of the growing commercial interest in kulfi and in consonance with the planned modernization attempts of the traditional milk products technology, efforts have been made here to consolidate the available information on composition, sensory attributes and method of production.

Many technological similarities would exist between kulfi mix powder, dried ice cream mix and whole milk powder. The relevant informations available on milk drying techniques and factors affecting storage stability of dried ice cream mix and whole milk powder have also been reviewed hereunder.

2.1 KULFI

2.1.1 PRODUCT DESCRIPTION

According to Indian Standards (IS: 10501-1983), kulfi is a frozen dessert obtained from concentrated milk prepared from cow milk or buffalo milk or a combination thereof. It is uniform in consistency and free from both big sized ice crystals and coagulated milk particles. The product sold in the market has whitish to slight brownish appearance, compact body, icy texture and nutty, caramel flavour.

2.1.2 TRADITIONAL METHOD OF PRODUCTION

Small vendors usually condense milk without prior standardization in an

open karahi and incorporate sugar near the finishing stage of the condensation process. After cooling, the mix may be added with crushed nuts such as almonds, pistachio, etc. and flavours. Mix is then distributed in conical or cylindrical moulds made of galvanized iron sheets, aluminium or plastic. Filled moulds are closed with a lid and the edges made air tight with the help of wheat-dough. The mix-in-moulds is immersed in a large earthen vessel containing a mixture of ice and salt in the ratio of 1:1 (Warner, 1976). The product frozen without air incorporation consequently results in coarse icy texture (De, 1980).

The cottage scale technique used by kulfi vendors is of little value for industrial adoption. The conventional method of kulfi making was partially improved by Salooja and Balachandran (1982) which comprised of standardization of cow milk to 3.5 per cent fat and 8.5 per cent SNF, slow heating of milk in a steam jacketed vessel with constant stirring until the milk solids level reached 26 per cent, addition of sugar (13 per cent) and filling into moulds. The moulds were immersed in freezing mixture of ice and coarse salt in the ratio of 4:1 accompanied by intermittent shaking.

2.1.3 CHEMICAL COMPOSITION OF KULFI

Wide variations in the chemical composition of kulfi were observed due to differences in the initial composition and quality of milk, amount of sugar added and the method of manufacture. The proximate chemical composition of kulfi as reported by the different workers is depicted in Table 1.

The total solids content in kulfi samples collected from the markets and those prepared in the laboratories ranged from 30.1 to 49.3 per cent, fat from 3.4 to 14.0 per cent, SNF from 9.9 to 18.3 per cent, protein from 2.1 to 5.0 per cent and sucrose from 13.0 to 20.0 per cent. It would be evident that the researchers had different perceptions and product description in mind.

Ashokraju et al. (1989) manufactured kulfi with total solids ranging

Table 1. Chemical composition of kulfi

Author(s)	Sample source	Constituents (per cent)				
		Total solids	Fat	SNF	Protein	Sucrose
Rao (1978)	Market	30.1-49.3	3.4-6.5	*	2.1-3.4	13.0-20.0
Salooja (1979)	Experimental	39.0	10.7	15.2	*	13.0
Salooja and Balachandran (1982)	Experimental	39.0	7.9	18.3	*	13.0
Yerriswamy et al. (1983)	Market	36.0-41.4	3.5-11.0	10.5-10.7	2.5-4.9	*
Yerriswamy et al. (1983)	Experimental	38.2-40.2	13.0-14.0	9.9-12.1	4.6-5.0	*
Bandyopadhyay and Mathur (1987)	Market	*	7.0-8.0	17.0-18.0	*	13.0-15.0
PFA Standard (1976) (Min. values)	Market	36.0	10.0	*	3.5	*
Indian Standards (IS: 10501-1983) (Min. values)	Market	35.0	8.0	*	3.5	13.0

* Values not reported

from 35.8 to 75.0 per cent. Milk was concentrated in an open pan by traditional method. Kulfi samples prepared with 48 per cent TS and 3.0 per cent starch were rated as the best from sensory stand point. The market samples analysed by several workers (Table 1) were quite different in chemical composition when compared with the laboratory samples. Some of the market samples failed to meet the minimum legal requirements prescribed in the PFA rules (1976). Even within the different constituents, there were wide variations in the market samples of kulfi. It was pointed out by Salooja and Balachandran (1982) that if cow milk with 3.5 per cent fat and 8.5 per cent SNF is concentrated to 26.0 per cent of milk solids, the samples of kulfi will fall short of statutory requirement with regard to fat.

In the traditional kulfi making practice, no emphasis is placed on quality assurance. The variation in the chemical composition of kulfi would, therefore, continue to exist unabated. Unless optimized product mix formulation is introduced in the market, it would be difficult for the consumers to have the access to the availability of uniform quality kulfi throughout the year.

2.1.4 MICROBIOLOGICAL QUALITY OF KULFI

Most studies on microbiological quality of kulfi published in past were related to ascertaining the extent of contamination and the possible health hazards associated with the consumption of such product (Table 2). Pathogenic strains of E. coli attracted considerable attention in view of their suspected role in the outbreaks of gastro-enteritis in men and animals. As regards the occurrence of enteropathogenic E. coli in frozen milk products, six pathogenic serotypes, namely 026:B6, 055:B5, 0111:B4, 0119:B14, 0126:B16 and 0127:B8, had been isolated from kulfi (Singh and Ranganathan, 1974). The serotypes 055:B5 and 0126:B16 are frequently associated with infantile diarrhoea.

Staphylococci in milk and milk products have drawn considerable attention

Table 2. Microbiological quality of kulfi

Microbial counts (cfu/g)	Rao (1978)	Yerriswamy et al.(1983)		Batish et al. (1984)	Kahlon and Grover (1984)	Batish and Chander (1987)	IS:10501 (1983)
	Market samples	Market samples	Experimental samples	Market samples	Market samples	Market samples	
Total Plate Counts ($x10^5$)	0.072-1300.0 (28.0)	0.26-85.6	0.245-0.53	1.7-66000.0 (10000.0)	4.0-400.0 (7.0)	2.9-6000.0 (45.0)	2.5 (Max.)
Staphylococci ($x10^5$)	0.001-440.0 (1.3)	-	-	-	6.5-69.0 (14.0)	0.05-9.0 (0.45)	-
Coliforms ($x10^3$)	0.004-5100.0 (29.0)	0.06-1.98	0.004-0.006	-	-	-	0.10 (Max.)
Enterococci ($x10^3$)	0.01-1200.0 (2.3)	-	-	0.01-320.0 (32.0)	-	-	-
Psychrotrophs ($x10^4$)	0.016-320.0 (39.0)	-	-	-	-	-	-
Yeast and Moulds ($x10^3$)	0.05-130.0 (15.0)	-	-	-	-	-	-

Figures in parentheses represent mean values

in recent years as potential food poisoning organisms due to their ability to produce enterotoxins under favourable conditions. High incidence of staphylococci in 15 kulfi samples collected from Karnal market was reported by Ghosh (1970) and the count ranged between 4.3×10^3 and 59×10^3 with an average of 13.9×10^3 per g. The incidence of staphylococcal thermonuclease was also encountered in market samples of kulfi by Rao et al.(1980) and Kahlon and Grover (1984). Enterotoxins (A and B) were detected in thermonuclease positive samples (Rao et al., 1980). Preformed enterotoxins and thermostable deoxyribonuclease present in raw milk due to staphylococcal contamination can survive subsequent heat treatment and carried over to milk products like khoa and kulfi (Varadaraj and Nambudripad, 1986; Batish and Chander, 1987).

Enterococci, because of their ubiqutious nature, are invariably present in milk and milk products. In view of their ability to resist low temperatures and other unfavourable conditions, these organisms are likely to be present in frozen dairy products, indicating the prevalence of improper sanitary conditions during processing (Brooks, 1974). Among the enterococci isolated from kulfi, S. faecalis var. faecalis was the predominant type followed by S. faecalis var. zymogenes, S. faecalis var. liquefaciens and S. faecium (Batish and Ranganathan, 1984). Thermonuclease positive enterococci, S. faecium and S. faecalis var. faecalis showing pathogenicity and enterotoxigenicity were also detected in some samples of kulfi (Batish et al., 1984). These organisms were reported resistant to antibiotics like streptomycin and penicillin (Batish and Ranganathan, 1986).

The foregoing review highlights the significance of good quality raw milk in the preparation of kulfi. The present trade practices in kulfi making place no credence to microbiological quality. It is now evident that market kulfi can serve as a potential source of pathogenic organisms and their toxins

until stringent quality control measures are administered at all stages of manufacture and handling. The reported occurrence of toxigenic enterococci exhibiting multiple drug resistance in market samples of kulfi must be viewed rather seriously as a possible health hazard and full adoption of scientific principles of production made statutorily compulsory.

2.2 FUNCTIONS OF DIFFERENT CONSTITUENTS OF KULFI

Kulfi is a complex mixture of several ingredients like dairy products and non dairy products. The dairy ingredients (milkfat and MSNF) are basic to kulfi making. The non dairy products include sweeteners, stabilizers, colour, flavour and other additives. The functional properties of the different basic ingredients used in the mix formulation may be quite varied. The role of different constituents in kulfi making is discussed in the succeeding sections.

2.2.1 MILK FAT

The use of correct proportion of milk fat is essential to balance the mix properly and to meet the minimum legal standards. Milk fat contributes a characteristic creamy taste and mellowness to the product. It also gives the kulfi a smooth texture that is difficult to obtain by any other means. Fat contributes to the body and melting resistance of the product.

Salooja and Balachandran (1982) reported that the mix containing 7.9 per cent milk fat produced kulfi with most desirable texture and body. The PFA standard for kulfi prescribes a minimum of 10 per cent fat. A proposal is pending before the Central Committee for Food Standards to reduce the fat requirement in kulfi to 8 per cent.

Yerriswamy et al. (1983) suggested that milk fat percentage in the range of 13 to 14 will produce a superior product. It would appear that no definite recommendation can be made at this stage, unless additional evidence through systematic research is built up with regard to the minimum fat content in kulfi.

2.2.2 MILK-SOLIDS-NOT-FAT (MSNF)

It is common knowledge that proper amount of milk-solids-not-fat (MSNF) help in producing a desirable body, prevent the product from becoming buttery in texture. Milk proteins in MSNF make the product compact and smooth, and thus prevent the formation of weak body and coarse texture.

According to Salooja and Balachandran (1982), kulfi containing 18.3 per cent MSNF should be judged as best in terms of body and texture. Higher MSNF (20.5 per cent) gave a product of heavy and soggy body, while lower MSNF (16.2 per cent) resulted in a weak and crumbly body. Yerriswamy et al. (1983), on the contrary, claimed that 9.9 to 12.2 per cent MSNF will produce kulfi with superior body and texture. It is difficult to draw any conclusion on the basis of these two reports. An optimum figure for MSNF in kulfi making needs to be arrived at so that commercial establishments can benefit from such findings.

The recent trend has been to incorporate less expensive non dairy ingredient like starch, into kulfi mix. Samples of kulfi prepared with 3.0 per cent starch and 18 per cent MSNF showed superior organoleptic properties (Ashokraju et al., 1989).

2.2.3 SWEETENERS

The sweetening agent is an important ingredient in kulfi as it improves the palatability and adds to the total solids of the product. The most popular sweetener is cane sugar. However, other sweetening agents like beet sugar, corn syrup and invert sugar are also used in ice cream. Since soluble components influence the freezing point, an optimum level of sugar must be used to get a desired body and texture besides avoiding the risk of excessive sweetness.

A satisfactory level of cane sugar in kulfi was reported to be 13.0 per cent by Salooja and Balachandran (1982) whereas Yerriswamy et al. (1983) suggested a sugar level of as high as 15.0 per cent.

High fructose corn sweeteners (HFCS) are cheap substitutes for sucrose. HFCS has increasingly been used in recent years for partial replacement of sucrose in ice cream and other desserts (Honer, 1981). It controls the sweetness and crystallization, enhances the appearance (gloss, luster and clarity) and improves the texture and cohesiveness of ice cream. However, its application in kulfi making has not been investigated.

2.2.4 STABILIZERS

The primary purpose of using stabilizers in kulfi and other frozen dairy desserts is to (1) produce uniformly smooth body and texture, (2) retard ice crystal growth during freezing and storage, and (3) provide resistance to melting. Stabilizers function through their ability either to form gel structures in water or to combine with water as water of hydration (Arbuckle, 1986). Among the stabilizers used in the manufacture of kulfi and other frozen dairy products, sodium alginate, guar gum and isabgol husk are important.

2.2.4.1 Sodium Alginate

Sodium alginate is the salt of alginic acid extracted from brown algae of the class, phaeophyceae (Sanderson, 1981). Alginates contain D-mannopyranosyluronic acid unit (M) and L-gulopyrasosyluronic acid unit (G). The M/G ratio in the stabilizers differs from source to source and influences the solution properties. Viscosity of alginate solution decreases as the temperature is raised. It is influenced only slightly by pH change in the range of 4 to 10.

The optimum level of sodium alginate recommended in ice cream from buffalo milk is 0.3 per cent (Minhas et al., 1984) and that for kulfi 0.15 per cent (Ashokraju et al., 1989). Since no overrun is desired in kulfi, it would be necessary to know whether lower or higher percentages of this stabilizer will be ideal.

2.2.4.2 Isabgol Husk

Isabgol husk (Psyllium seed husk) is obtained from Plantago sp. which is cultivated in Western parts of India. It is made up of arabino-xylan units (Southgate, 1984). Upadhyay et al. (1978) evaluated the potential of isabgol husk as an ice cream stabilizer. Addition of 0.3 and 0.4 per cent isabgol husk imparted good body and texture to ice cream. Miglani et al. (1987) reported that the relative viscosity of ice cream mix increased from 2.50 to 15.25 when the level of isabgol husk increased from 0.1 to 0.5 per cent. It was shown that isabgol husk has a potential for commercial exploitation as a cheap substitute for sodium alginate in ice cream.

Isabgol husk is reported to have cholesterol lowering effect (Anderson, 1987). When the respondents were administered 'Metamucil' (Psyllium hydrophilic mucilloid) about 15.0 per cent reduction in blood cholesterol was observed.

2.2.5 FLAVOURS

Frozen desserts are valued for their pleasant flavour and cooling and refreshing effects.

The flavouring materials are of three types, viz., natural or true flavour, artificial or imitation flavour and compound flavours, made by combining natural flavour with artificial flavour. The most commonly used flavours in ice cream are vanilla, chocolate, cocoa, fruit extracts, coffee, nuts and caramel (Arbuckle, 1986). However, Jain and Verma (1972) reported from their consumer preference studies that beside vanilla, orange and pineapple are also most liked flavours in ice cream in India.

The most preferred flavour in kulfi is, however, natural cardamom. Cardamom is the fruit of Elettaria cardamomum. The seeds contain 3.0 to 5.0 per cent of an aromatic oil. The chief constituents of cardamom oil are

limonene, eincole, alpha-pinene, terpinyl acetate and borneol (Swaminathan, 1974). Addition of a mixture of spices consisting of cardamom, pistachio and almonds in the ratio of 1:2:2 at the rate of 0.5 per cent by weight in kulfi mix before freezing improved the flavour (Rao, 1978).

2.3 PROCESSING CONDITIONS

The processing conditions during product manufacture influence the mix properties as well as the final quality of frozen desserts. The importance of those unit operations have been reviewed here.

2.3.1 HEAT TREATMENT

Proper heat treatment of all the dairy product mixes is essential to destroy all the pathogenic organisms and form a uniform mixture of ingredients. Heating improves the flavour and keeping quality of the products.

According to Indian Standard (IS: 10501-1983) the optimum time temperature combination for pasteurization of kulfi mix is 68.5°C for 30 min or 80.0°C for 25 sec. The recent trend is towards higher temperature and lower holding time.

Yerriswamy et al. (1984) reported that kulfi mixes containing 37 to 40 per cent total solids and heat treated at 121°C for 15 min produced very good quality kulfi in terms of organoleptic scores. Spores in all the samples of sterilized kulfi mix were absent and the keeping quality of sterilized kulfi mix in the sealed bottles was more than 3 months at room temperature.

2.3.2 HOMOGENIZATION

The main purpose of homogenization is to make a permanent and uniform suspension of the fat by reducing the size of the fat globules preferably to less than 2 micron. Homogenization helps in imparting smooth texture and body characteristics besides rich flavour and greater digestibility of fat (Arbuckle,

1986) and makes the product glossy and stable (Schmidt and Smith, 1987). The benefits of homogenization in kulfi making have not been elucidated.

2.3.3 FREEZING AND HARDENING

The freezing process of ice cream consists of two phases. First the mix is quickly frozen at -4°C to -6°C while being agitated to incorporate air in such a way that the product forms the small ice crystals necessary to give smoothness and expected overrun. Secondly, when the ice cream is partially frozen to certain consistency, it is drawn from the freezer into packages and quickly transformed to cold rooms (maintained at -20°C to -25°C) where the freezing and hardening processes are completed without agitation (Arbuckle, 1986).

Freezing of mix is one of the most important operations in the manufacture of kulfi. Both quality and palatability of the finished product depend upon the freezing technique.

Salooja (1979) reported that freezing kulfi in conventional salt/ice freezer and partial freezing in mechanical freezer followed by hardening increased the stiffness of the product and decreased the melt down rate, compared with the product prepared by direct freezing without agitation. Yerriswamy et al. (1984) found that kulfi mix whipped and partially frozen in refrigerator and hardened in salt and ice mixture at -15°C for 3 to 4 hr resulted in a product of good organoleptic quality.

2.4 PHYSICO-CHEMICAL PROPERTIES OF MIX

The different constituents exert profound influence on the physico-chemical properties of kulfi mix. The physico-chemical properties like acidity, pH, surface tension, viscosity and melting quality are altered because of the changes in the relative proportions of constituents and processing parameters.

2.4.1 ACIDITY AND pH

The normal acidity of kulfi mix is due to milk proteins and mineral salts. Any increase in MSNF raises the acidity and lowers pH. Salooja (1979) reported that the average acidity values of kulfi mix prepared with 17, 20, 23, 26 and 29 per cent MSNF were 0.187, 0.217, 0.236, 0.286 and 0.383 respectively with corresponding pH values of 6.62, 6.52, 6.50, 6.41 and 6.32. Sterilization of kulfi mix at 121°C was found to increase the titratable acidity and decrease the pH (Yerriswamy et al., 1984). Addition of 0.15 per cent sodium alginate in kulfi mix containing 48.12 per cent total solids was found to increase the pH value from 6.25 to 6.30 (Ashokraju et al., 1989).

2.4.2 SURFACE TENSION

Surface tension is a force resulting from an attraction between surface molecules of a liquid that gives surface film like characteristics. The greater the attraction between the molecules, the higher the surface tension. The normal surface tension of ice cream mix ranges from 48 to 53 dynes/cm. It decreases with the increase of surface active agents like emulsifiers, proteins, etc. A decreased surface tension favours faster rate of air incorporation in the mix during the freezing process (Arbuckle, 1986).

Surface tension of kulfi mix decreased from 50.76 to 45.02 dynes/cm with increasing level of total milk solids from 17 to 29 per cent and this was due to higher concentration of proteins and other organic substances (Salooja, 1979).

2.4.3 VISCOSITY

Viscosity is the resistance of a liquid to flow. It is internal friction which tends to resist the sliding of one part of the fluid over another. At one time high viscosity was believed to be important, but for fast freezing in modern equipment, a lower viscosity seems desirable. The average values for

viscosity of kulfi mix expressed as sec/100 revolutions were observed to increase from 34.62 to 58.08 with increase in milk solids (17 to 29 per cent) due to higher concentration of MSNF and high fat content leading to partial clumping of fat (Salooja, 1979). Viscosity of ice cream increased to 62.8 cP with pregelatinized potato starch added as stabilizer (Bhandari, 1982).

Yerriswamy et al. (1983) reported that kulfi mix containing 37.1 to 40.3 per cent total solids had a viscosity range of 28.1 to 36.6 cP but after sterilization of the same mix at 121°C the viscosity got increased from 66.53 to 128.53 cP (Yerriswamy et al., 1984).

2.4.4 MELTING RESISTANCE

The melt down rate is dependent upon the constituents, total solids and processing conditions of kulfi mix. Salooja (1979) reported that the average values for melt down rate of kulfi expressed as volume (ml) collected in 15 min were 12.8, 13.2, 20.4, 14.4 and 14.8 for samples having 17, 20, 23, 26 and 29 per cent milk solids respectively. The addition of sodium alginate and starch to kulfi mix reduces the melt down rate of kulfi (Ashokraju et al.,1989). Increased lactose concentration caused the depression in the freezing point of the mix. Because of freezing point depression, the amount of water frozen in kulfi for a given temperature decreased and the amount of water remaining unfrozen was more, due to which the rate of melting was higher. A correlation between milk solids concentration and freezing temperature, rate, etc. need to be worked out for industrial production of kulfi.

2.5 SPRAY DRYING OF MILK PRODUCTS

The basic principle of spray drying consists in atomizing the milk, preferably pre-heated and concentrated, to form a spray of very minute droplets (fog-like mist) which are directed into a large, suitably designed drying

chamber, where they mix intimately with a current of hot air. Owing to their large surface area, the milk particles surrender their moisture practically instantaneously and dry to a fine, hollow, spherical particles with some occluded air.

Spray drying is an economical and gentle drying method for industrial applications. This method has successfully been employed in the manufacture of buffalo whole milk powder (Mrithyunjaya and Bhanumurthi, 1987), butter milk powder (Masters, 1982), dried srikhand (Mahajan et al., 1979), dried co-precipitates (Barabas et al., 1980), fruit flavoured milk powder (Sharma, 1972), ice cream mix powder (Bhandari and Balachandran, 1984), malted milk food (Salooja and Balachandran, 1988), and khoa powder (Ranganadham, 1988).

The evaporating capacity and thermal efficiency of the dryer is dependent on the difference between the air inlet and outlet temperatures under constant feed rate and specific total solids content (Knipschildt, 1986). Greater the difference between the two temperatures, higher the evaporation capacity. Inlet air temperatures as low as 160°C and as high as 260°C are used. Similarly outlet temperatures of 73° to 100°C are employed in the manufacture of different dried milk products depending upon the properties of liquid feed and the desired quality attributes of the dried products. Air inlet and outlet temperatures employed in the manufacture of different dairy products are given in Table 3.

2.6 PROPERTIES OF SPRAY DRIED MILK PRODUCTS

The composition and treatment of product mixes, different methods of drying and other processing conditions influence the quality of dried products to a great extent. The major quality attributes of dried milk products as affected by the various processing treatments are reviewed to utilize this knowledge in the production of kulfi mix powder.

Table 3. Inlet and outlet air temperatures employed in the manufacture of different dried milk products

Author(s)	Product	Inlet air temperature (°C)	Outlet air temperature (°C)
Sharma (1972)	Mango milk powder, banana milk powder	170-175	100
Mahajan et al. (1979)	Srikhand powder	180-200	100
Barabas et al. (1980)	Co-precipitates	260	85
Bhandari and Balachandran (1984)	Ice cream mix powder	160	73
Mrithyunjaya and Bhanumurthi (1987)	Buffalo whole milk powder	195±5	90±2
Ranganadham (1988)	Khoa powder	190	88
Salooja and Balachandran (1988)	Malted milk	195±10	90±2

2.6.1 CHEMICAL QUALITY

2.6.1.1 Chemical Composition

The quality of milk powders depends on the kind of milk used and its fat and MSNF ratio. Chemical composition of whole milk powder (WMP) and other dried milk products as reported by different workers is presented in Table 4. Residual moisture is one of the most important properties of milk powder both from the quality and economic point of view. The quality specifications lay down the maximum permissible limits for moisture content to achieve the desired shelf-life. The economic aspect demands that the limit of maximum moisture content be approached as closely as possible, while at the same time ensuring that no portion of the product will exceed this moisture level. Moisture content in WMP ranges from 2 to 5 per cent. The Bureau of Indian Standards (IS: 1165-1975) recommends a maximum limit of 4 per cent moisture in WMP. Since moisture is a limiting factor in storage of WMP and other fat rich products at room temperature, attempts are made to reduce the moisture to bare minimum during the manufacturing process.

The large particles have a high moisture content. Thus, if atomization is inadequate or large particles are being produced deliberately, the moisture of the powder, under otherwise identical drying conditions, will be higher (Woodhams and Murray, 1974).

Vilder et al. (1976,1979), Kerekreti (1980) and Salooja and Balachandran (1988) reported that higher moisture content in powder can be obtained by increasing the total solids of concentrated mix (preventing fine atomization) and by decreasing boththe speed of the atomizer and the outlet air temperature.

Most statutory standards prescribe a minimum fat level of 26 per cent in WMP. Lactose content ranged between 36.1 and 41.5 per cent due to differences in chemical composition of milk. Wide variations in ash content are reported.

Table 4. Chemical composition of whole milk powder and other dried milk products

Author(s)	Product	Moisture	Fat	Protein	Lactose	Ash	Sucrose
		Per cent					
Tseng (1978)	WMP	2.3-2.9 (3.15)	26.4-27.5 (27.08)	25.4-27.4 (26.13)	36.1-38.5 (37.65)	4.7-5.6 (5.53)	-
Miocinovic and Ostojic (1983)	WMP	2.6-4.9	24.1-27.5	23.6-27.7	37.5-41.5	3.6-7.1	-
Mrithyunjaya and Bhanumurthi (1987)	WMP	2.1-2.30	26.0-27.0	-	-	5.5-5.7	-
Bhandari (1982)	Ice cream mix powder	1.8	31.0	10.1	12.8	2.1	40.5
Ranganadham (1988)	Khoa powder	2.5	33.1	25.4	33.9	4.9	-

Figures in the parentheses represent mean values

Miocinovic and Ostojic (1983) observed that the ash content in WMP varies from 3.6 to 7.1 per cent. As per IS: 1165 (1975), the maximum ash content in WMP should not exceed 7.3 per cent on dry matter basis.

2.6.1.2 Free Fat

The presence of free fat in dried milks is of great importance as it affects the oxidative stability during storage and reconstitution properties (Hall and Hedrick, 1975). Because of the hydrophobic nature of fat, the wetting property is partly affected by the amount of free fat present on the particle surface. Higher free fat content in dried whole milk was observed to increase the oxidation of fat and decrease the dispersibility (Kopecky, 1978).

Increased forewarming temperature and prolonged holding time of milk contributed to increased free fat content in spray dried whole milk (Reinke et al., 1960) and khoa powder (Ranganadham, 1988). Increased fat content in milk increases the free fat content of WMP more so when unhomogenized (Buma, 1971c).

Excessive release of free fat can be minimised by increasing the dry matter content in the concentrate and its homogenization before drying (Kirst, 1981), and increasing the inlet temperature and lowering the outlet temperature (Vilder et al., 1976).

2.6.2 PHYSICAL PROPERTIES

The range of manufactured milk powders has extended steadily over the past few years. The physical properties required in them have become increasingly important from the stand point of quality control, packaging, transportation and subsequent product uses. Some of the physical properties that may be relevant to kulfi mix powder are reviewed in order to adopt them for developing new technology for instant spray dried kulfi mix powder and finally for quality evaluation.

2.6.2.1 Bulk Density

It is defined as weight per unit volume of powder and normally expressed as g per ml (g/ml). High bulk density is of great value in products intended for bulk shipment for saving the space, packaging material and transport costs. Bulk density is influenced by product's composition, particle density and the amount of interstitial air. The presence of occluded air within the particle and the manner in which these particles are packed together influence the bulk density. In spray dried milk powders, bulk density varies between 0.35 and 0.65 g/ml (Lewis, 1987). An increase in dry matter of milk concentrate results in a powder with high bulk density (Kerekreti, 1980). A slight increase in particle density of milk powders from 0.90 to 0.92 g/ml was achieved when viscosity of the concentrate increased from 0.7 to 1.6 poise (Baldwin et al., 1980).

Normally milk powder contains between 10 and 30 ml of entrapped air in 100 g powder. The amount of entrapped air decreases with an increased total solids in the concentrate (Kerekreti, 1980). Nozzle atomization typically results in 10 to 15 ml of entrapped air per 100 g, while centrifugal atomization under the same conditions entraps 20 to 25 ml (Neilsen and Hansen, 1982). Bulk density decreases with increase in atomization speed (Vilder et al., 1976; Knipschildt, 1986). An increase in inlet air temperature causes quicker shell drying of droplets and, therefore, formation of greater number of vacuoles during diffusion evaporation (Bloore and Boag, 1982; Knipschildt, 1986).

The powder particle packing depends on their shape and size. Small particles will pack in the voids left between large particles leading to higher bulk density. Anticaking agents reduce inter particle forces and increase the bulk density of powder (Peleg and Bagley, 1983). Addition of refined sucrose also increases the bulk density of powders (Bhandari and Balachandran, 1984). No information on bulk density of kulfi mix powder has been published.

2.6.2.2 Particle Size Distribution

The particle size distribution of powder is a measure of average particle diameter and spread of sizes in either side of this average. The proper particle size distribution ensures that the space between the large particles is filled with smaller ones. Too many small particles (less than 80 um) are undesirable because of increasing dustiness, lumpiness and the way they affect free flowability (Baldwin and Sanderson, 1973). It is possible to extend the particle size distribution spectrum towards larger particles by increasing the feed concentration (Baldwin et al., 1980) or reducing the velocity of the rotary wheel (Bhandari and Balachandran, 1988). A slight agglomeration has a positive influence on bulk density and improved powder flowability. However, excessive agglomeration is definitely harmful.

2.6.2.3 Flowability

Flow property is described by the ease with which the powder particles move with respect to each other. Fat content and particle size in milk powders control the flowability (Peleg, 1977). Increased concentration of milk before drying was found to increase the particle size of WMP (Baldwin, 1977) and malted milk powder (Salooja, 1983) resulting in high flowability. Lower free fat content in powder increases the free flowing properties (Pisecky, 1988).

Addition of free flowing agents to milk powder significantly improves the flowability. Anticaking agents are very fine powders of fairly inert chemical substances added to milk powders with much larger particle size (Peleg and Bagley, 1983). The well known anticaking agents are: Zeolex (sodium aluminium silicate), tricalcium phosphate and calcium silicate. The recommended dose ranges from 0.5 to 1.0 per cent of the powder (Whatson, 1957). Addition of calcium silicate at the rate of 1.5 per cent before or after drying was

claimed to have improved the flow properties of milk powders (Cipolla et al., 1961). Sodium calcium silicate addition at the rate of 1.0 per cent improved the flow property of khoa powder during storage at 30°C (Ranganadham, 1988).

2.6.2.4 Wettability

Wettability of milk powder is primarily a measure of its hydrophilic property and expressed as the ability of a heap of powder to be wetted and to penetrate the surface of still water. It is measured as the time (sec) necessary for a given amount of powder to pass through the water surface at a specified temperature. Wettability depends mainly on the nature of surface of the particle. In general, large size particles with irregular shape provide more space in the interstices for wetting rather than the small particles of symmetrical shape which enhance close packing of particles and thus inhibiting the penetration of water (Kreveld, 1974).

The presence of fat at the surface of WMP particles inhibits wetting of particles (Baldwin and Sanderson, 1973; Pijanowski et al., 1974). Increasing the forewarming temperature of milk from 75°C to 85°C was found to cause a reduction in wetting time from 13.8 to 12.3 sec in spray dried malted milk (Sanooja, 1983). An increase in wettability of milk powder manufactured from high solids preconcentrate was observed by Baldwin et al. (1980) and Shuvaev et al. (1981). This change could possibly be affected by the increased particle size of powder by higher milk solids concentration. Wettability of milk powders improves considerably by homogenization of condensed whole milk. Homogenization influences the formation of hydrophilic whey protein coating on the fat globules leading to increased wettability (Dosaka et al., 1980). Wettability can also be improved by adding surface active agents (Samhammer, 1972) or by increasing the atomizer speed (Salooja and Balachandran, 1988).

2.6.2.5 Dispersibility

This property permits the milk powder to be distributed uniformly throughout water. It is related to the ease with which lumps and agglomerates fall apart. Good dispersibility is generally linked with large particle size determined by the type of atomization and visocisty of concentrated milk. Small particles tend to retard dispersibility due to over drying. Small particles tend to flocculate and cause lumping. In the absence of large number of fine particles, water penetrates early into the lumps and cause them to disperse uniformly (Woodhams and Murray, 1974).

When the amount of fine particles (less than 80 um) was greater than 15 to 20 per cent by weight, lump formation was observed (Baldwin and Sanderson, 1973). Lascelles and Baldwin (1976) observed that best dispersibility was achieved at a reconstitution temperature of 60°C and it improved as the percentage of fine particles below 80 um decreased. Increased atomizer speed caused a decrease in dispersibility of dried malted milk (Salooja and Balachandran, 1988).

2.6.2.6 Solubility

Milk powder, immediately on its initial contact with water, gets wet on the particle surfaces followed by water absorption, swelling and solubilization of some constituents. The solubility is referred as the rate of dissolution (solubility per cent) and the total solubility (solubility index). Solubility of WMP depends on the particle size, the state of fat in dried milk and the drying conditions (Mol and Jensen, 1974). Solubility index increased from 0.60 to 0.74 as the temperature of forewarming is increased from 75 to 95°C (Salooja, 1983).

Precondensing improves the solubility of spray dried milk (Kabanov and Kharitonov, 1978). An inverse relationship exists between degree of concentration

and solubility (Salooja, 1983). Homogenization of concentrated whole milk before drying improved the solubility of milk powder (Kharitonov, 1974) and greater degree of atomization increased the solubility (Salooja and Balachandran, 1988).

2.6.2.7 Water Activity (a_w)

The sorption and desorption of water vapour by foods has received special attention because of its importance in shelf life. Water activity and sorption isotherms are affected by the composition and temperature of the food. Proteins sorb preferentially at low a_w and the usual order for milk powder is casein (a_w 0.01 to 0.03), whey proteins (a_w 0.05 to 0.35), lactose (a_w 0.2 to 0.6) and milk salts (a_w 0.6 to 1.0) (Kinsella and Fox, 1986). In milk powder at a_w range near 0.6 there is a transformation in physical state of lactose to crystalline structure (Linko et al., 1982). Non-enzymatic browning is frequently an important form of deterioration in dried milk products. Increase in browning was noted as a_w of milk powder reached 0.44 (Chang et al., 1985).

Water activity also influences the oxidation of fat and enzymic activity in dried milk products. The rate of oxidation gets to minimum in the a_w range of 0.2 to 0.4. The reacting constituents become soluble at a_w above 0.4 and more in solvent water to increase oxidation rate (Rizvi, 1986). Although most enzymes are inactive below a_w 0.8, enzymatic activity can still be observed at very low a_w, e.g., lipase activity in dried products (Lewis, 1987).

Water activity in a dried food product has a tremendous effect on bacterial growth and survival. Majority of bacteria have their maximum growth at a_w between 0.99 to 0.995 (Sperber, 1983). By lowering the a_w below 0.90, the growth of most bacteria can be arrested (Jacobson, 1985). Almost all microbial activity is inhibited at a_w below 0.6, more specifically moulds below 0.7 and yeasts below 0.8 (Lewis, 1987). Lower water activity (< 0.6) in dried milks

is the limiting factor for the growth and multiplication of microorganisms and hence microbial spoilage of milk powder rather uncommon.

2.6.2.8 Microstructure

The electron micrographs of milk powders are influenced by the physical state of various milk constituents at the time of production, drying systems and storage conditions. Microstructure of spray dried milk shows the presence of spherical entities of various sizes. Small surface folds and cracks are observed on the surface of WMP (Buma and Henstra, 1971a). Deep surface folds and dents were absent in WMP (Buma and Henstra, 1971b) and the powder particles carry a large vacuole in the centre. Spray WMP particles are usually porous and the vacuoles in these particles connected with interparticle space (Buma, 1978). WMP prepared from homogenized concentrated milk showed the presence of small holes. Fat bridges were observed between the particles of spray WMP (Buma, 1971a). Many particles of spray dried skim milk show deep surface folds and dents caused by shrinkange of casein during drying (Buma and Henstra, 1971b).

The particles of spray dried ice cream mix containing pregelatinized potato starch were almost spherical in shape and had a more or less rough contour and each particle had a thick, viscid layer around it. Fracturing revealed that the particles were comparatively solid bodies with a few randomly distributed air cells (Bhandari et al., 1984).

Ranganadham (1988) reported that the spray dried khoa powder carried spherical particles of different sizes with some folded structures. The surface pits which are indicative of free fat were present in abundance in khoa powder and much less in number on WMP particles. The internal structure of khoa powder was found to contain a large central vacuole and numerous tiny vacuoles. Studies on microstructure of kulfi mix powder have not been attempted so far.

2.6.3 MICROBIOLOGICAL QUALITY

The usual drying procedure results in destruction of most of the micro-organisms present in the original milk. Low moisture content in milk powders prevents the growth of microorganisms surviving the heat treatments. The studies on the microflora in dried milks have been the subject of several groups of research workers (Table 5).

The microflora of spray dried milks are made up of thermoduric micrococci, thermoduric streptococci and Corynebacteria, aerobic spore formers and miscellaneous organisms. With the advent of high pre-heat treatment in processing of milk, near-sterile powder could be produced with limited post-heat treatment contamination. Although higher inlet temperature (200°C) offers much protection to powder, it fails to remove all spore formers (Stadhouders et al., 1982).

Dried milks are known to contain coliform bacteria which are responsible for food poisoning out-breaks. Some pathogenic strains of E. coli can survive pasteurization and subsequent drying temperature, thus posing a potential danger to consumers health (Ghodekar et al., 1980). Sen et al. (1989) reported that spray drying of milk using air inlet temperature of 200°C and outlet temperature of 90°C was sufficient to destroy all the coliforms in the dried milk, but staphylococci were found to survive this temperature combination. The coagulase and DNase-producing staphylococci have also been isolated from dried milks (Ghodekar and Nambudripad, 1989; Rajmany et al., 1989).

The enumeration of moulds in dried milk products was carried out by Jesenska et al. (1984) who isolated Penicillium cladosporium, Rhizopus and Aspergillus spp. Among these, Aspergillus flavus was found to produce aflatoxin B_1 in dried milk products.

Table 5. Microbiological quality of milk powders

Particulars (cfu/g)	Reddy et al. (1984)	Dass et al. (1986)	Kwee et al. (1986)	Muir et al. (1986)	Arora and Sudarsanam (1986)	Stone and Evans (1986)
Standard Plate Count	$4.3-89.0 \times 10^3$	4.3×10^4	7.4×10^3	NA	21×10^3	NA
Thermoduric Count	$772-335 \times 10^2$	NA	6.2×10^3	4.4×10^3	NA	NA
Coliform Count	0-5	NA	NA	NA	182	NA
Enterococcal Count	NA	7.1×10^2	NA	NA	6.4×10^3	NA
Staphylococcal Count	NA	NA	NA	NA	952	NA
Spore Count(Total)	270-440	NA	80	1.5×10^3	2.4×10^3	
Mesophilic Spore	NA	NA	NA	NA	NA	2.0×10^2 - 1.3×10^4
Thermophilic Spore	NA	NA	NA	NA	NA	1.0×10^1 - 3.9×10^4
Yeast and Mould Count	NA	NA	NA	NA	5.2×10^3	NA

The Prevention of Food Adulteration Rules (1955) prescribe a maximum per g count of total bacteria at 15,000 and coliform count as 90. Bureau of Indian Standards (IS: 1165-1975) also specify similar microbiological standards for milk powders. No standards have been laid down for spore count as well as yeast and mould count under these two standards. As a result of extensive survey, Nikodemusz (1978) of Hungary suggested that aerobic spore forming bacteria and moulds in dried milks should not exceed 1,000 and 100 per g respectively.

2.7 LECITHINATION OF WHOLE MILK POWDER

It is generally observed that when normal milk powder is mixed with water under low shear conditions, the powder forms balls upon the water surface, which can only be dispersed by relatively rigorous agitation. This property of milk powder inhibits its use under normal household conditions. The development of instant milk powder has considerably enhanced the use of dried milks for liquid milk substitution.

Powders containing fat cannot be readily reconstituted in water at temperatures below 45°C due to hydrophobic nature of the fat. Even 0.1 per cent free fat is sufficient to make the powder water-repellent. It is possible to overcome this water repelling property by providing a wettable surface with a surface active agent like lecithin. Lecithin is the most acceptable additive because it is the natural component of milk (Pisecky, 1980).

The WMP intended for lecithination must have free fat content as low as possible and not exceed 4 per cent of the total fat. The bulk density should be in the range of 0.45 to 0.50 g/ml and powder should consist of porous agglomerates with an absence of fines. The greater portion should have particle sizes between 100 and 250 um, with a maximum of 15 to 20 per cent below 90 um (Knipschildt, 1986).

In commercial practice, lecithination is carried out in a fluid-bed when the powder has been dried to its final moisture content. A 1:1 mixture of lecithin and butter oil heated to 70°C is sprayed onto the powder in the fluid bed by means of nozzle, and in a quantity to give lecithin content of 0.2 per cent in the powder. The temperature of powder during lecithination should be approximately 50°C and powder must be held for at least 5 min at this temperature (Vilder, 1987). Interestingly, lecithin dispersed in water instead of lecithin-butter oil mixture was found to be equally effective in improving the instant property of dried whole milk. Partially dehydrated milk was treated with 8 lit water per 100 kg powder in the second section of the fluid bed. Addition of 0.35 per cent lecithin on the weight of powder was reported to be optimum (Vilder, 1989).

2.8 PACKAGING OF DRIED MILK PRODUCTS

The primary purpose of packaging of any food is to protect it from the external contamination and to contain it for bulk or retail distribution and sales. A good packaging material also contributes to extension of shelf life. Packaging systems and materials form an integral part of present day production technology in dried milk products.

The major considerations for selecting a packaging material for fat rich dried milk products are the sensitivity of powders to ingress of moisture, uptake of oxygen, odour and bacteria, and exposure to light (Cummins, 1976; Tokley, 1982). Other factors in deciding the package include bulk density and cohesivity of milk powders (Lovell, 1972; Dua, 1979).

The characteristics of few packaging materials likely to be useful for packaging of kulfi mix powder are reviewed here.

2.8.1 METAL CAN

Metal can is nearly a perfect container for milk powders. Tin plate usually has a thickness varying from 0.15 to 0.5 mm and coated on both sides with a thin protective film (0.4 to 2.5 mu) of commercially pure tin. Food grade lacquer (usually epoxy phenolic type coating) is applied on the food contact surfaces for preventing both rusting and interaction of tin with food. The internal appearance of the metal can also gets improved besides providing greater protection against internal corrosion and staining reactions.

Tin can was found to be best for packaging of WMP (Tuohy, 1984), SMP (Driscoll et al., 1985) and spray dried khoa powder (Ranganadham, 1988). However, tin is relatively scare, expensive and subjected to considerable price fluctuations compared with other packaging materials. High cost exerts serious limitation on wider use of tin in food packaging (Malin, 1980).

2.8.2 METALLIZED POLYESTER

Metallized polyester film consists of a plastic material covered with a metallic layer. Metallizing process is accomplished by evaporating a suitable metal by means of heat and condensing it on the surface to be coated. Vacuum conditions greatly facilitate the metallizing process (Cyril, 1978). Metallized layer is basically made up of an initial layer of spherical metallic particles which become embedded in the plastic material. Subsequent layers are then built up of metal to metal particles. Most package requirements recommend a thickness of 12 micron polyester (Dulin, 1978; Schaar and Skodis, 1982). Metallized polyester laminates save about 15 to 20 per cent in material costs besides saving of extra laminating process as compared with other laminated packing materials (Anon, 1978).

Promising results were obtained by Tuohy (1984) in packing WMP in plastic

film laminates containing a metallized polyester film layer. Vacuum packaging of WMP in oxygen impermeable flexible metallized polyester film laminate offered about the same shelf life as that obtained by canning under inert gas (Tuohy, 1985). Metallized polyester gave a shelf life of 10 months to ice cream mix powder (Bhandari, 1982), 6 months to WMP (Mrithyunjaya and Bhanumurthi, 1987) and 7 months to khoa powder (Ranganadham, 1988) at storage temperatures of 30°C.

2.9 CHANGES DURING STORAGE OF MILK POWDERS

Shelf-life is the length of time the food product under normal storage and distribution conditions keeps fit in an acceptable form. The chemical composition, processing, packaging and storage conditions exert great influence on the shelf-life of products. The fat rich milk powders need special attention during storage, especially in the tropical countries where summer temperatures may go as high as 47°C. Fat rich products, when stored at ambient temperature, may undergo physical and chemical changes involving the lipid and non-lipid constituents and the rates of such reactions are accelerated at elevated temperature and levels of moisture and oxygen in the product. The quality of dried milk packed in industrial packs (consisting of kraft paper and polyethylene bags) and stored at 30°C with 95 per cent RH got distinctly deteriorated in 12 months (Vilder, 1982). On the other hand, dried milk packed in plastic bags with saturated humidity deteriorated after 8 weeks of storage at 15°C (Kang et al., 1983). WMP from buffalo milk stored at 30°C showed a shelf-life of 6 months (Mrithyunjaya and Bhanumurthi, 1987) and khoa powder could keep good for 7 months (Rangandham, 1988).

Some of the important changes that occur in dehydrated milk products during storage are reviewed hereunder.

2.9.1 CHANGES IN COLOUR

The colour of dried milk products changes during prolonged storage. The change in the colour especially browning is known to be affected by the amount of reducing sugars and proteins present in the product. The method of drying and storage conditions, especially temperature and humidity, also influence the changes in colour during storage.

Kopecky (1978) reported that the browning rate of milk powder was accelerated by increased moisture content and temperature during storage. Spray dried lactose-hydrolysed infant milk food when stored at 37°C for 12 months also showed the development of brown discolouration (Paul, 1984).

2.9.2 5-HMF CONTENT

5-HMF formed during storage of dried milk products as a browning intermediate is used as a marker of interaction between milk proteins and reducing sugars. The concentration of HMF increases with length of storage (Luquet et al., 1988) more so at high moisture content (Reynolds, 1963). A gradual increase in HMF content during storage was clearly witnessed in WMP (Vilder, 1982) and in SMP (Golubovic et al., 1983) more so when added with iron and vitamin A (Caric et al., 1984). Mrithyunjaya and Bhanumurthi (1987) observed an increase in HMF content from 2.47 to 7.64 umoles/lit in WMP on storage at 37°C for 6 months. Ranganadham (1988) noticed a remarkably high increase in HMF content from 31.63 to 69.84 umoles/lit in spray dried khoa powder on storage at 30°C for 8 months.

2.9.3 MOISTURE CONTENT

Although powder is not a sterile product, its reduced water content ($\sim$ 4 per cent) and lower water activity($a_w < 0.6$) do not permit microbial growth and enzymic activity. Dried milks may, however, absorb water from environment

during storage if not protected properly. Increased water content leads to browning and caking of powders. The amorphous lactose in dried milk is very hygroscopic (Wursch et al., 1984). A gradual increase in moisture content of dried milks from 2.15 to 2.47 per cent during storage is possible (Mrithyunjaya and Bhanumurthi, 1987) either due to absorption of moisture from the surroundings or to absorption of water released in Maillard reaction (Coulter et al., 1948).

2.9.4 CHANGES IN FAT

The changes in fat during storage mainly depend upon the lipid make up of the product, temperature, relative humidity (RH) during storage and packaging material. The major changes associated with fat of milk powders include increase in free fat, oxidation and hydrolytic rancidity.

Free fat content in WMP increases gradually on storage. The increase is affected by the moisture content, increasing rapidly when the latter exceeds 6 per cent (Truyen, 1975; Kirst, 1981). With the absorption of moisture, lactose crystallization takes place leading to changes in free fat content (Kopecky, 1978). Increases in free fat during storage are related with storage temperature and milk powder porosity (Kirst, 1981). Relative humidity at which the product is stored has higher impact than the storage period in increasing free fat content (Lasztity et al., 1980). A gradual increase in free fat content from 5.20 to 7.40 was noted in spray dried buffalo WMP on storage for 6 months at 30°C (Mrithyunjaya and Bhanumurthi, 1987). Free fat content (as per cent of total fat) in spray dried khoa powder increased from 62.48 to 67.80 per cent on storage for 8 months at 30°C (Ranganadham, 1988).

High fat content in WMP favours oxidation during storage leading to the formation of aldehydes, ketones and other related compounds due to the oxidative breakdown of unsaturated fatty acids. The off flavours related with oxidation

can be detected at peroxide value above 0.5 meq.O_2/kg fat (Hill, 1955). Tallowy flavour was noticed in dried whole milk stored upto 8 months (Radayeva et al., 1974). An increase in peroxide value from 0.19 to 0.42 meq.O_2/kg fat was noticed in preterm infant formula on storage at 30°C for 12 months (Rao, 1985). Higher preheat treatment retarded the peroxide formation in preterm infant formula. Fat oxidation in WMP exhibited an initial linear phase which gradually changed to an exponential phase with the rapid development of oxidation product-hexanal which is an effective off flavour compound (Hall et al., 1985). TBA value (in terms of optical density at 530 nm), an index of fat oxidation, increases fast at higher temperature of storage, reaching a maximum of 0.05 at 37°C in 24 weeks and 0.3 after 8 week storage at 60°C (Tuohy et al., 1982).

Although the occurrence of hydrolytic rancidity in WMP is not so common as the oxidative deterioration, lipolytic enzymes are still active in low moisture product like milk powder (Tarassuk and Jack,1949). Hydrolytic rancidity in dry milk can result either from lipolysis during storage or when powder is made from milk which had undergone lipolysis before drying. An increase in free fatty acids in dried whole milk stored at 20°C/72 per cent RH and 30°C/55 per cent RH was observed by Vilder (1982). However, the acid degree of fat in powder has to be about 4.0 or above before hydrolytic rancidity can be recognized organoleptically (Shipstead and Tarassuk, 1953).

2.9.5 ACIDITY AND pH

Acidity and pH of dried milks are important in several chemical reactions that affect the shelf-life of the product. Interaction of amino groups of the protein with lactose would be expected to cause a decrease in pH and an increase in titratable acidity. Coulter et al. (1948) and Henry et al. (1948) have demonstrated that these effects occur during storage of dry milk. Storage of

SMP with high moisture at 20°C changed the pH of reconstituted milk from 6.80 to 6.55. Nitrogen gas packing and low storage temperatures to certain extent prevent the change in pH (Henry et al., 1948). A gradual decrease in pH from 6.78 to 6.69 was noted in high heat skim milk powder on storage for 12 months at 30°C (Kieseker and Clarke, 1984). However, no substantial change in pH occurred in lactose hydrolysed infant formula stored at 37°C for 12 months in the presence of nitrogen (Paul, 1984). pH and acidity changed from 6.70 to 6.60 and 1.08 to 1.11 respectively in spray dried khoa powder stored for 8 months at 30°C (Ranganadham, 1988).

2.9.6 FLOWABILITY

During storage, dried milks undergo some changes that affect their free flowing properties. The changes in flowability of dried milks during storage largely depend on the moisture uptake by the product which results in lump formation and caking (Peleg, 1977). The type of packaging material, therefore, plays an important role in flowability. An increase in angle of repose (tan θ) from 62.93 to 66.16 was observed in spray dried malted milk on storage for 12 months at 30°C (Salooja, 1983). Flowability of lactose hydrolysed infant formula decreased from 0.90 to 0.86 after storage for 12 months at 37°C (Paul, 1984). The flowability of spray dried khoa powder decreased with a corresponding increase in angle of repose (tan θ) from 64.0 to 69.3 on storage for 8 months at 30°C as a result of absorption of moisture and release of free fat during storage (Ranganadham, 1988).

2.9.7 WETTABILITY

Wettability of dried milks gradually decreases during storage (Kuznetsov, 1979). The time taken for complete wetting of lactose hydrolysed infant formula gradually increased from 9.2 to 25.18 sec on storage at 37°C for 12 months (Paul, 1984). The loss of wettability is more pronounced in high heat treated milks.

Ranganadham (1988) observed an increase in wetting time from 30.2 to 40.5 sec in spray dried khoa powder made from 102°C/15 min preheat treated concentrate, after 8 months storage at 30°C. Large quantities of free fat released during storage of dried milks were found to be responsible for reduced wettability (Lasztity et al., 1980).

2.9.8 DISPERSIBILITY

Reduction in the dispersibility in dried whole milk during storage was caused by increased free fat component of the powder (Kuznetsov, 1979). A slight reduction in dispersibility from 32.9 to 31.6 g was observed in malted milk food after storage for 12 months at 30°C (Salooja, 1983). Similar trend was noted in lactose hydrolysed infant formula stored for 12 months at 37°C (Paul, 1984).

2.9.9 SOLUBILITY

There is a gradual loss of solubility on storage and this is more so when stored at high temperatures. The protein carbohydrate interaction was reported to cause decrease in solubility (Colos and Segena, 1979).

A decrease in solubility was noted in high heat non-fat dry milk stored at 30°C for 18 months by Kieseker and Clarke (1982). Mrithyunjaya and Bhanumurthi (1987) observed an increase in solubility index from 1.07 to 1.80 ml in dried buffalo whole milk on storage at 30°C for 6 months. An increase in solubility index from 1.2 to 2.0 ml was observed in spray dried khoa powder stored at 30°C for 8 months in tin cans (Ranganadham, 1988).

2.9.10 MICROBIOLOGICAL QUALITY

Bacterial counts in milk powder tend to decrease considerably on storage and reach a point of no change after two to four months. Reduction in bacterial numbers depends on storage conditions. Bacterial flora tend to die out more

rapidly as the temperature of storage is raised. In spray dried SMP, standard plate count decreased from 1.2×10^5 to 1.8×10^4 after 6 months storage at room temperature (Arun et al., 1979). Mesophilic count reduced from 4.1×10^3 to 2.2×10^3; thermophilic count from 4.2×10^2 to 140 and thermoduric count from 4.4×10^3 to 1.7×10^3 in low heat SMP on storage at 30°C for 6 months (Muir et al., 1986).

Coliforms tend to die out more rapidly on storage of milk powder. Viable coliform count of 51 to 60 per g in SMP decreased rapidly and disappeared after 6 months of storage (Arun et al., 1980).

Spores are relatively unaffected during storage. Spore count in high heat SMP decreased from 4.5×10^2 to 4.0×10^2 per g on storage at 30°C for 6 months (Muir et al., 1986). In spray dried khoa powder, there was a marginal decrease in spore count from 108 to 102 per g during 10 months storage at 30°C (Ranganadham, 1988).

2.10 IMPROVING STORAGE STABILITY OF MILK POWDERS

The major problems associated with spoilage of milk powder during storage are browning and oxidation of milk fat. Browning can be prevented to large extent by keeping the moisture content of the dried product to low level and subsequently preventing moisture absorption with the help of impervious packaging and employing low temperature storage (Golubovic et al.,1983). Oxidative changes in WMP can be prevented by limiting oxygen in the product by vacuum packaging, flushing with inert gases and by the addition of antioxidants.

2.10.1 OXYGEN LIMITATION TECHNIQUE

The most practical commercial procedure for extending shelf-life of WMP is to lower the oxygen content in the packed dried whole milk. By reducing the oxygen to 2 per cent or less in the head space, the keeping quality of the powder

can be doubled. The dried milk product can be vacuum packaged with low oxygen level (Tuohy et al., 1982). Replacement of head space air of the container with nitrogen or carbon dioxide gas is a common practice in the dairy industry (Hall and Hendrick, 1975). Mrithyunjaya and Bhanumurthi (1987) and Ranganadham (1988) successfully employed nitrogen gas packing for enhancing the shelf-life of buffalo WMP and spray dried khoa powder respectively.

2.10.2 ANTIOXIDANTS

Sulphydryl compounds released during high temperature heat treatments in the manufacture of dried milk act as antioxidants and improve the keeping quality. Incorporation of permitted antioxidants in small amounts to fluid milk before dehydration helps in extending the shelf-life of powders (Hall and Hendrick, 1975). In India, no antioxidant other than butylated hydroxy anisole (BHA) is permitted in WMP under the provisions of Prevention of Food Adulteration Rules (1955). Addition of BHA at the rate of 0.0025 per cent to concentrated milk before spray drying resulted in a product with greater flavour stability during storage (Hall and Lingnert, 1984). Addition of 0.01 per cent BHA on product basis in spray dried buffalo WMP resulted in lower TBA value (0.0037) in terms of optical density at 530 nm than the control samples (0.005) after storage at 37°C for 6 months. A marginal improvement in shelf-life of spray dried khoa powder was observed due to addition of BHA at the rate of 0.01 per cent of the product (Ranganadham, 1988).

The literature reviewed in this chapter would reveal that milk drying has developed into a highly sophisticated industry. The manufacture of special powders, i.e, khoa powder, malted milk food, kulfi mix powder with specific properties may be of increasing importance in consonance with the changing life styles and dietary requirements of the consumers and will no doubt be more rewarding than the manufacture of standard skim milk and whole milk powders.

It may be concluded that processing conditions largely influence the physico-chemical, microbiological and nutritional attributes of spray dried milk products and their shelf-life indicating the need for careful selection of processing parameters for the manufacture of good quality kulfi mix powder.

CHAPTER 3

SCOPE AND PLAN OF WORK

3. SCOPE AND PLAN OF WORK

3.1 SCOPE OF STUDY

The review of literature presented in Chapter 2 concludes that at present no appropriate method is available for industrial production of kulfi. The market samples of kulfi showed large variations in the chemical composition, flavour, texture and microbiological quality. Moreover, consumers' preferences for quality attributes of kulfi are not well known. The unhygienic conditions prevailing at the kulfi making establishments and apathy of the traders for adopting scientific and sanitary practices of product manufacture pose serious health risks to consumers.

The demand for kulfi is growing with leaps and bounds. The present study has, therefore, been undertaken with a view to establish the consumers' preference for quality attributes of kulfi so that an optimum composition and processing conditions could be recommended. The production of instant kulfi mix powder using spray drying technology is conceived as a profitable proposition for dairy plants possessing condensing and drying facilities. At the present moment, all such dairy plants are manufacturing dried skim milk, whole milk powder and baby foods. Availability of technology for the manufacture of instant kulfi mix will enable these factories to undertake the production of high revenue generating product. This will also help in profitable utilization of regional and seasonal surpluses of milk. For small producers of frozen dairy products, who may not have adequate facilities for storage and processing of raw ingredients, the instant mixes can be made readily available. A potential market can be created in towns, cities and households for kulfi mix powder, which after reconstitution can be frozen in domestic ice cream freezers or

earthen pots. The selection of a suitable packaging material and use of anti-oxidant for extending the shelf-life of instant kulfi mix powder also formed the scope of this study. Instant kulfi mix powder suitably packaged and with guaranteed shelf-life could easily become an item of export.

Recognizing the need for developing an instant kulfi mix powder, this investigation was planned with the following objectives.

1. Characterization of sensory, physical, chemical and microbiological properties of most selling market samples of kulfi and to identify consumers' preference for quality attributes.

2. Formulation and optimization of processing conditions for the manufacture of kulfi mix.

3. Standardization of spray drying conditions for the production of kulfi mix powder.

4. Extension of shelf-life of dried kulfi mix using permitted antioxidant, flavouring and packaging (materials and systems).

5. Estimation of cost of production of kulfi mix powder.

6. Marketability of the kulfi mix powder at the Institute Milk Parlour.

3.2 PLAN OF WORK

For the fulfilment of the above stated objectives, the following studies were undertaken.

3.2.1 Trade practices in the manufacture of kulfi and characterization of sensory, chemical and microbiological properties of most preferred samples of kulfi.

3.2.1.1 Trade practices in manufacture of kulfi:

i) Batch size,

iii) Package types,

iv) Freezing method,

v) Hardening,

vi) Vending systems.

3.2.1.2 Characterization of sensory quality:

i) Colour and appearance,

ii) Flavour,

iii) Body and texture.

3.2.1.3 Characterization of physical properties:

i) Melt down,

ii) Viscosity,

iii) Surface tension.

3.2.1.4 Characterization of chemical quality:

i) Total solids,

ii) Fat,

iii) Protein,

iv) Sucrose,

v) Ash,

vi) Acidity,

vii) Starch,

viii) p-dimethyl amino benzaldehyde reactivity.

3.2.1.5 Characterization of microbiological quality:

i) Total viable count,

ii) Coliform count,

iii) Rapid coliform test,

iv) Staphylococcal count,

v) Thermostable DNase test,

vi) Yeast and moulds count.

3.2.2 Formulation of kulfi mix and optimization of processing conditions.

3.2.2.1 Optimization of ingredient mix:

i) Fat levels - 7.0, 9.0, 11.0 and 13.0 per cent

ii) SNF levels - 14.0, 15.0, 16.0 and 17.0 per cent

iii) Cane sugar levels - 14.0, 15.0 and 16.0 per cent

iv) Stabilizer levels:

a) Sodium alginate - 0.1, 0.2, 0.3 and 0.4 per cent

b) Isabgol husk - 0.1, 0.2, 0.3 and 0.4 per cent

3.2.2.2 Optimization of processing conditions:

i) Homogenization pressure

1000/500, 1500/500 and 2000/500 psi
(6.86/3.43, 10.29/3.43 and 13.72/3.43 MPa)

ii) Heat treatments

100°C for 5, 10 and 15 min

3.2.2.3 Methods of freezing and hardening:

i) Traditional method (salt and ice mixture),

ii) Brine tank method,

iii) Batch freezer method,

iv) Direct hardening method.

The effects of different quantities of ingredients and processing conditions were evaluated according to the following plan:

I. Evaluation of kulfi mix

i) pH,

ii) Acidity

iii) Specific gravity,

iv) Surface tension,

v) Viscosity.

I. Evaluation of kulfi

i) Sensory properties,

ii) Per cent overrun,

iii) Melting rate,

iv) Total solids,

v) Fat.

3.2.3 Drying of kulfi mix by spray process.

3.2.3.1 Mix concentration - 40.0 and 45.0 per cent TS

3.2.3.2 Atomizer speed - 15,000, 20,000 and 25,000 revolutions per minute(rpm)

3.2.3.3 Inlet and outlet air temperatures - 170°/80°C; 180°/85°C and 190°/92°C

3.2.4 Packaging and extension of shelf-life of kulfi mix powder.

3.2.4.1 Type of packaging materials and systems:

i) Tin cans without inert gas and with inert gas packaging.

ii) Metallized polyester laminate.

3.2.4.2 Use of additive:

i) BHA - 0.01 per cent by weight of kulfi mix powder.

ii) Cardamom - 0.1, 0.2 and 0.3 per cent by weight of kulfi mix powder.

The effects of different drying conditions on fresh product and effectiveness of packaging materials during storage was evaluated according to the following plan:

. Sensory evaluation:

i) Colour and appearance,

ii) Flavour,

iii) Texture.

II. Physical properties:

i) Particle size distribution (fresh product only),

ii) Bulk density,

iii) Flowability,

iv) Wettability,

v) Dispersibility,

vi) Solubility,

vii) Microstructure,

viii) Colour.

II. Chemical properties:

i) Acidity and pH,

ii) Moisture,

iii) Free fat,

iv) Browning intermediate (5-HMF value),

v) Free fatty acids,

vi) Peroxide value,

vii) Available lysine,

viii) Lactulose.

IV. Microbiological quality:

i) Total viable count,

ii) Coliform count,

iii) Rapid coliform test,

iv) Staphylococcal count,

v) Thermostable DNase test,

vi) Yeast and mould count.

The kulfi mix powder after reconstitution was evaluated according to the following plan.

I. Physico-chemical properties of mix:

i) pH,

ii) Acidity,

iii) Specific gravity,

iv) Surface tension,

v) Viscosity.

I. Evaluation of kulfi:

i) Sensory evaluation,

ii) Per cent overrun,

iii) Melting rate.

3.2.5 Estimation of production cost of instant kulfi mix powder.

3.2.6 Marketability of the product by offering it for sale at Institute Milk Parlour.

CHAPTER 4

MATERIALS AND METHODS

4. MATERIALS AND METHODS

This chapter describes the quality of raw materials and various methodologies employed in process development. The techniques used for analytical, microbiological and sensory evaluation of kulfi and kulfi mix powder and the statistical procedures used in interpreting the results are also reported.

4.1 SELECTION OF MATERIALS

4.1.1 INGREDIENTS

4.1.1.1 Milk

Pooled, fresh, raw buffalo milk was obtained from the Experimental Dairy, National Dairy Research Institute, Karnal.

4.1.1.2 Cream

Fresh cream (approximately 50.0 per cent fat) extracted from fresh buffalo milk by centrifugal separation.

4.1.1.3 Concentrated Skim Milk

Buffalo skim milk with about 9.0 to 9.5 per cent solids-not-fat (SNF) was evaporated to 40 per cent total solids in a single effect evaporator under a vacuum of 0.83 to 0.87 Torr.

4.1.1.4 Cane Sugar

Refined cane sugar conforming to Indian Standards (IS: 1679-1960) was used in the manufacture of kulfi and kulfi mix powder.

4.1.1.5 Stabilizers

Isabgol husk (Psyllium husk) was procured from M/s. Keshav Lal Vithal Das Patel, Sidhpur 384 151 and sodium alginate was that of Loba-Chemie, Bombay.

4.1.1.6 Cardamom

Cardamom (Chhoti Elaichi) conforming to Indian Standards (IS: 1907-1966) was used as a natural flavouring.

4.1.1.7 Butylated Hydroxyanisole (BHA)

Butylated hydroxyanisole (BHA) - 'EMBANOX' May & Baker Ltd., England.

4.1.2 PACKAGING MATERIALS

4.1.2.1 Metallized Polyester Laminate

The preformed metallized polyester laminate pouches were supplied by M/s. Garware Plastics and Polyester Pvt. Ltd., Bombay with the following specifications:

Size of pouch	:	23 x 19 cm
Capacity of pouch	:	500 g
Thickness		
Metallized polyester	:	12 microns
LDPE	:	300 gauge
MVTR (38°C/90 per cent RH/hr)	:	14 to 20 g per m^2
Oxygen permeability (at atmospheric temp.)	:	85 to 90 ml per m^2 per 24 hr
Grease resistance	:	Very good
Cost of one pack	:	Rs.2.50

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4.1.2.2 Tin Plate Cans

Tin cans lacquered inside with the following specifications were used

for packaging kulfi mix powder. These were procured from M/s. Metal Box India Ltd., New Delhi.

Size of the tin can	:	7.4 dia x 10 cm height
Capacity	:	150 g
Thickness	:	0.016 inch
Gass barrier properties	:	Very good
Grease resistance	:	Excellent
Cost of one tin can	:	Rs.3.00

4.1.2.3 Nitrogen Gas

Food grade nitrogen gas supplied by M/s. Modi Gas Ltd. with the following specifications was used for flushing out air from the packages.

Min. purity	:	99.995 per cent
Max. moisture content	:	320 mg/1000 ft^3
Oxygen content	:	20 ppm
Non-volatile residue (usually CO_2)	:	1 ppm

4.1.2.4 Kulfi Mould

Screw capped anodised aluminium moulds with the following specifications were used for freezing and hardening of kulfi.

Bottom dia	:	2.5 cm
Top dia	:	5.0 cm
Height	:	7.5 cm
Volume	:	88.0 ± 2.0 ml
Cost per mould	:	Rs.3.00

4.2 METHODS OF MANUFACTURE

4.2.1 PREPARATION OF KULFI

A basic procedure described below was followed for the preparation kulfi. With this procedure several formulations with varying percentages fat, SNF, cane sugar and stabilizers were investigated as outlined in section 4.2.2.1 in order to arrive at most acceptable formulation of kulfi.

The control kulfi samples were prepared in accordance with Indian tandard recommendations (IS:10501-1983) with milk fat 8.0 per cent, MSNF 14.0 per cent and cane sugar 13.0 per cent. No stabilizer was added to it.

4.2.1.1 Figuring the Mix

The algebraic method was used for calculating the amount of each ingredient required to make a mix of known composition as outlined in section 4.2.2.1.

4.2.1.2 Mix Processing

Kulfi mix was heated to 65 to 70°C and homogenized in a Crepaco two-tage homogenizer using different pressure combinations listed in section 4.2.2.2. The control kulfi mix was not homogenized. This was followed by heating in a tubular heat exchanger at 100°C for 5, 10 and 15 min in order to possess the optimum time-temperature combination for flavour development. The control kulfi mix received a heat treatment of 85°C for 30 sec. The mixes were cooled first with running tap water and later with chilled water to a Temperature of 4°C. Cardamom seed powder was added to the mix at the rate of 4.2 per cent before freezing.

4.2.1.3 Freezing and Hardening

Four different freezing methods used to find out the best freezing

1. Traditional method: Metal cones filled with kulfi mix were immersed in the earthen pot filled with ice and salt mixture (3:1 ratio). The contents were shaken continuously for rapid and uniform freezing.

2. Brine tank method: The cones with product mix were immersed in a brine tank at a temperature of -20°C and shaken continuously till the mix in cones got frozen.

3. Batch freezer method: Kulfi mix was partially frozen and whipped in a batch type softy ice cream machine (Vulcan Laval, Type 5). Partially frozen mix (at -4°C and 30 per cent overrun) was filled in cones and hardening achieved at -23°C in a deep freezer room.

4. Direct hardening method: The filled kulfi cones were kept directly in a deep freezer room maintained at -23°C. There was no shaking or agitation of the cones.

4.2.2 PRODUCTION OF SPRAY DRIED KULFI MIX

Kulfi mix containing fat 11.0 per cent, MSNF 16.0 per cent, cane sugar 15.0 per cent and stabilizer (Isabgol husk) 0.2 per cent was rated as best by a panel of selected judges. This formulation was used as the base for further investigations.

The composition of the kulfi mix was modified so that the mix at the time of spray drying contained only 25.0 per cent of the total cane sugar. A total solids concentration of 40.0 per cent was found most appropriate for drying. Concentrated mix was pre-heated to 70°C and homogenized at 1000/500 psi (6.86/3.43 MPa). The mix was heated in a tubular heat exchanger at 100°C for 10 min to develop the cooked flavour. Heat treated mix was spray dried in an Anhydro spray drier (Type II with a water evaporation capacity of 35.0 kg/hr). The operating conditions were varied in respect of inlet and outlet air

temperature of 170° and 80°c; 180° and 85°C; 190° and 92°C; and atomizer speed 15,000; 20,000 and 25,000 rpm. Spray dried kulfi mix was collected and dry blended with the remaining amount of powdered cane sugar in the ratio of 100: 35.5 parts.

The kulfi powder samples prepared from different process variables were subjected to physico-chemical analysis and sensory evaluation. Kulfi mix powder produced under the optimum spray drying conditions was subsequently used for storage and instantization studies.

4.2.2.1 Packaging of Kulfi Mix Powder

The metallized polyester pouches were sterilized by exposing to ultra-violet rays for 15 min. Tin cans along with lids were sterilized in a hot air oven at 170° ± 5°C for 3 hr before use. Kulfi mix powder prepared under standardized spray drying conditions was cooled to 30°C and packed in each type of packaging material and sealed.

4.2.2.2 Nitrogen Gas Flushing

A pin hole was made at the back of the seamed can and placed in the vacuum chamber. Air was evacuated rapidly under a vacuum of 0.15 to 0.20 Torr maintained for 5 min. Nitrogen gas was flushed into the vacuum chamber and pressure of 2 psi (0.014 MPa) maintained for 5 min. At the end of one filling cycle, tins were removed the vacuum chamber and the pin hole sealed by soldering. Soldered tins were tested for any possible leaks by immersing in water for 2 min.

4.2.2.3 Storage of Kulfi Mix Powder

Kulfi mix powder samples packed in quantities of 150 g in tins and 500 g in metallized polyester laminates were stored at 30 ± 1°C (68 ± 5 per cent

4.2.3 LECITHINATION OF DRIED KULFI MIX

For lecithination, about 1.0 kg of kulfi mix powder was spread uniformly on a tray and tempered to 50°C in a hot air oven for about 30 min. It was then transferred to a dry blender. A calculated quantity of lecithin (2.0 g per kg of powder) was mixed with butteroil in the ratio of 1:1 with slight warming. This mixture was sprayed on the powder with constant agitation in the dry blender. The powder was uniformly spread in trays, transferred to a batch type casein drier and heated with air having an inlet temperature of 60°C for a period of 45 min for conditioning.

4.2.4 RECONSTITUTION OF DRIED KULFI MIX

Fresh samples of kulfi mix powder and those stored in the different packages were reconstituted immediately and at one month interval. The powder was mixed with water in the ratio of 1:1.3 parts by weight at 60°C and heated to 95°C for 2 min and cooled to 5 ± 1°C. Cardamom powder at the rate of 0.2 per cent was added to mix before freezing. Kulfi from reconstituted powder was assessed for flavour, body and texture, colour and appearance, and melting resistance in the same manner as for kulfi made with fresh ingredients.

4.3 ANALYTICAL METHODS

4.3.1 MOISTURE

Moisture content in kulfi and kulfi mix powder was estimated by oven drying method recommended by the ISI in SP:18 (1981).

4.3.2 SNF CONTENT

The SNF content in milk was estimated by lactometer method according to the method outlined in ISI (1982).

4.3.3 FAT

Fat content in milk and cream was determined by the Gerber method as described in ISI (1977a) and ISI (1977b) respectively. Fat percentages in kulfi and kulfi mix powder were estimated by solvent extraction method as recommended by ISI in SP:18 (1981).

4.3.4 LACTOSE

Lactose in kulfi and kulfi mix powder was estimated titrimetrically by the ISI procedure described in SP:18 (1981).

4.3.5 TOTAL PROTEIN

Total protein percentage in kulfi and kulfi mix powder was determined by the microkjeldahl method following the procedure of ISI in S:18 (1981).

4.3.6 TOTAL ASH

The amount of total ash in kulfi and kulfi mix powder was determined by incinerating the sample in a muffle furnace at 550°C as per the ISI method described in SP:18 (1981).

4.3.7 SUCROSE

Sucrose in kulfi and kulfi mix powder was estimated by difference, subtracting from 100 the sum of moisture, fat, protein, lactose and ash.

4.3.8 STARCH

Starch was detected according to the method described in IS:10501 (1983). Molten kulfi samples were diluted in water (1:1 dilution) and boiled in a test tube over a low flame and allowed to cool for a while. To this diluted kulfi sample was added about 0.5 ml of 0.1 per cent solution of iodine in potassium iodide. Appearance of blue colour which disappeared on boiling and

4.3.9 TITRATABLE ACIDITY (TA)

The TA of kulfi and kulfi mix powder was determined by indirect titration method. Two g of the sample was well ground in a beaker with a flat end glass rod by adding 3 ml of hot distilled water and diluted with another 7 ml hot distilled water. Later, 10 ml of 0.1 N sodium hydroxide solution was added and contents mixed thoroughly. After adding 1.0 ml of phenolphthalein indicator (0.5 per cent w/v), the contents were titrated against 0.1 N hydrochloric acid with continuous stirring till the pink colour completely disappeared. Acidity was expressed as lactic acid per 100 g of product.

$$\text{Per cent lactic acidity} = \frac{10 \sim V}{W} \times 0.9$$

where, V = volume of 0.1 N hydrochloric acid required for titration

W = weight of sample (2 g)

4.3.10 pH

Molten kulfi samples were rendered homogeneous in a glass beaker with flat end glass rod. Fifty ml of the prepared sample was taken in a beaker and tested for pH at 30°C by direct immersion of electrode into the sample. For kulfi mix powder exactly 14.0 g sample was reconstituted with 100 ml distilled water and tested for pH as described earlier. A digital pH meter, Model L-1-122 (Elico Pvt. Ltd.,Hyderabad) was used. pH meter was calibrated with the standard buffer solutions at 30°C each day before use.

4.3.11 SPECIFIC GRAVITY

A 50 ml capacity specific gravity bottle was taken and kulfi mix or molten kulfi samples were weighed at 20°C. Weight of distill water was recorded under identical conditions and specific gravity calculated as under:

$$\text{Specific Gravity} = \frac{\text{Weight in g of the sample}}{\text{Weight degree of distilling water}}$$

4.3.12 RELATIVE VISCOSITY

The relative viscosity of kulfi mix was determined according to the method suggested by Miglani et al. (1987) using a Stromer's viscometer (Arthur H. Thomas Co., Philadelphia, USA). Well mixed kulfi mix samples at 20°C were taken in a beaker of 250 ml capacity (internal dia 6.5 cm) upto a predetermined fixed level so that the surface of the mix touched the mark on the shaft of the blade of the viscometer when the beaker was placed on the platform and raised. The lever was then released to allow the 50 g weight to drive the blade. The time (sec) taken by the pointer on the dial to make one revolution (100 divisions on the dial) in the mix was recorded. Similar reading was taken for distilled water. The relative viscosity was calculated as follows:

$$\text{Relative viscosity of kulfi mix (at 20°C)} = \frac{\text{Time taken in the mix}}{\text{Time taken in water (25.0 sec)}}$$

4.3.13 SURFACE TENSION

Surface tension of kulfi mix was determined by using a Torsion Balance (White Electrical Instrument Co. Ltd., England) as per the procedure outlined in the instruction manual supplied by the company. The equipment is designed to measure the surface tension of liquids, using a platinum ring. It is pre-calibrated in Newtons (0.00-0.12) per meter with 240 equal divisions and 1 Newton per meter is equivalent to 1,000 dynes per centimeter.

The samples at 20°C were taken in a watch glass and placed on the platform, which was raised, after locking the arm carrying the ring, till the ring was immersed in the mix. The lock was then released and the platform was lowered while simultaneously moving the pointer arm to keep the index line opposite the reference line, till the ring was separated from the mix. At this point, the reading was recorded and the value of surface tension calculated in dynes per cm. The ring was cleaned after each determination by rinsing first with distilled water and then with petroleum ether and ethanol.

4.3.14 OVERRUN

The overrun in market samples of kulfi was determined as per the procedure described in ISI:SP:18 (1981) using n-amyl alcohol in order to break the surface tension of the melted kulfi and to release the incorporated air.

The overrun of kulfi during mechanical freezing in an ice cream freezer was determined by the following formula:

$$\text{Per cent overrun} = \frac{\text{Weight of the known volume of kulfi mix} - \text{Weight of the same volume of kulfi}}{\text{Weight of the same volume of kulfi}} \times 100$$

4.3.15 MELT DOWN

Melt down quality was measured by emptying the kulfi samples from the moulds on an iron wire mesh (8 sq per linear inch) placed over a glass funnel as suggested by Ashokraju et al. (1989). The whole assembly was kept over a glass measuring cylinder (100 ml), and held undisturbed for 30 min in a chamber maintained at 30 ± 1°C without air circulation. The volume collected in the cylinder was noted and expressed as melt down for 30 min.

4.3.16 FREE FAT

Ten g of kulfi mix powder was placed in a glass stoppered (250 ml) conical flask. To the flask, was added 100 ml of petroleum ether (40°-60°C boiling range) and thereafter shaken for 10 times in a vertical motion. The solvent layer was decanted off into a solvent dish. Two such extractions of fat were found adequate to extract all the free fat. After evaporation of the solvent, free fat was expressed as percentage of total fat in kulfi mix powder. This method was adopted from Hall and Hedrick (1975).

4.3.17 FREE FATTY ACIDITY (FFA)

A 50 g portion of finely comminuted kulfi mix powder was transferred to a 500 ml glass stoppered conical flask and 150 ml of chloroform added. The

contents were stirred vigorously and allowed to stand for 4 hr with occasional shaking. Chloroform was decanted and evaporated in a vacuum oven. Fat extracted by this method was dissolved in neutralized ethanol and titrated at 70°C against 0.01 N sodium hydroxide using phenolphthalein as an indicator as described in the IS:3508 (1966).

4.3.18 PEROXIDE VALUE

A known amount of fat extracted from kulfi mix powder using chloroform as a solvent was used for measuring peroxide value following the method recommended in the IS:3508 (1966).

4.3.19 PARADIMETHYL AMINO BENZALDEHYDE (p-DMAB) REACTIVITY

p-DMAB reactivity of kulfi and kulfi mix powder was estimated by the colorimetric method of Kumar and Hansen (1972) with certain modifications as suggested by Ranganadham (1988).

4.3.20 5-HMF VALUES

The method of Keeney and Bassette (1959) as adopted by Craig et al. (1961) was used for estimating the total HMF content in kulfi mix powder.

Ten ml of 10 per cent reconstituted product was taken in a 50 ml screw capped test tube, followed by addition of 5 ml of 0.3 N oxalic acid and boiling in a water bath for one hour. After cooling to room temperature, five ml of 40 per cent TCA solution was added to each tube. The contents were mixed and filtered through Whatman No. 42 filter paper. To 4.0 ml of filtrate, one ml of 0.05 M aqueous solution of TBA was added and the tubes were placed in a water bath at 40°C for 30 min. After cooling to room temperature, the absorbance was measured in a spectrophotometer (Spectronic 20, Bausch & Lomb) at a wave length of 443 nm against a blank prepared in the same way substituting water for milk. The sum of free and potential HMF was calculated as follows:

Total HMF [free+potential] = [Absorbance-0.055] x 87.5 in micrmoles per 100 g

4.3.21 AVAILABLE LYSINE

Available lysine content of protein is calculated by measuring the decrease in moles of dye bind when the available lysine epsilon amino groups are blocked prior to reacting with Acid Orange-12 dye. Binding is on a "one mole: one mole" basis. *UDY Model-M Protein Analyser (Udytec, USA)* was used, which permits mechanised operation in testing.

The samples of kulfi mix powder representing about 80 mg and 120 mg of proteins were taken in sample bottles marked 'A' and 'B' respectively. In each bottle, 1 ml of isopropanol was added. To bottle 'B' was added 0.3 ml of propionic anhydride followed by 4.0 ml of 5 per cent sodium acetate [$3H_2O$] solution. This was shaken for 15 min and 40 ml of Acid Orange-12 (the dye solution contains 1.32 g/lit or 3.77 m moles/lit) added into each bottle following the addition of 4.3 ml sodium acetate solution in bottle 'A'. All the bottles were thereafter shaken for 60 min to attain equilibrium. After removing cap from each bottle and adding 0.25 g of filter aid, filter disc was placed in the dropper cup and the required volume of filtrate (35 to 30 drops) squeezed out directly to the UDY cuvette with a 0.3 mm path length in a UDY Model-M Protein Analyser (Udytec, USA). Absorbance was taken at 480 nm and compared with UDY reference dye (0.600 mg/ml). Available lysine was calculated using the following formula. The molecular weight of lysine is 146.3.

$$\text{Lysine (\% total protein)} = 14.63\ [(0.151-0.129\ C_A)/W_A - (0.151-0.129\ C_B)/W_B]$$

where, C_A and C_B are dye concentrations in bottles A and B respectively and

$$W_A \text{ or } W_B = \frac{A \times W_s}{\text{Per cent protein} \times (C_1 - 0.630)}$$

C_1 = 1.25 intercept

A = 5.48, slope calculated for milk sample for the equipment

W_s = Weight of sample taken

4.3.22 LACTULOSE

Lactulose content of kulfi mix powder was determined by HPLC method as described in IDF Standard:E56 (1988). A 5 per cent solution (5 g to 100 ml) of kulfi mix powder was prepared for lactulose determination. The equipment and the operating conditions were set as follows:

Water Model 510 Pump and Model 410 Differential Refractometer. Column was a Bio-Rad HPX 87P sugar column held at 75°C with a carbo P guard column and a Bio-Rad de-ashing column. Eluent was water at a flow rate of 0.3 ml/min. Run time and injection volume was 35.0 min and 20 uL respectively. Lactulose content was expressed as mg/100 g of sample.

4.3.23 COLOUR

The colour of kulfi mix powder was measured to determine the extent of browning with a Reflectometer (Model CL-28, Elico Pvt. Ltd., Hyderabad) using the principle of reflectance spectroscopy.

The reflectometer was first standardized with the standard white (magnesium oxide) and grey blocks in the white light. The sample filled in glass petri plate was then placed under the search unit using a blue filter (450 nm) and reflectance values recorded. At least five such observations were made on each petri plate at different points.

4.3.24 PARTICLE SIZE

Particle size of kulfi mix powder was determined microscopically by the method of Beckett et al. (1962). From each sample, two sub-samples were prepared by placing about 0.2 g of powder in each of two vials containing 5 ml of mineral oil. Two smears were prepared from each sub-sample by placing two drops separately on a slide and covering each carefully with a cover slip. The smears were examined microscopically with the 10X occular and 45X high dry

objective. The sizes of the particles were recorded in intervals of 0-1, 1-2, 3-4, 4-5 divisions and onwards on the occular micrometer. As one division was equal to 3.6 microns, the particle diameter was measured in 1.8 micron groupings. Fields were selected at random and all particles classified. One hundred particles were classified per smear for a total of 400 particles in each sample. The average particle size was calculated by the following formula:

$$\text{Average diameter (based on numbers)} \quad d_{av} = \frac{\sum_{1}^{i}(n_i d_i)}{\sum_{1}^{i} n_i}$$

where 'i' was each interval of classification, 'n_i' was the number of particles in the 'i^{th}' interval and 'd_i' was the diameter of the particle.

4.3.25 BULK DENSITY

Bulk density of kulfi mix powder was determined by the method given by Hall and Hedrick (1975). A 100 ml dry graduated cylinder was weighed and filled with dry mix to the 100 ml mark. The weight of dry mix was recorded. The 'packed' bulk density was determined by tapping the cylinder till the volume attained a constant level. The volume occupied was noted and results expressed as g/ml.

4.3.26 FLOWABILITY

The angle of repose (as a static measure for flowability) of kulfi mix powder was determined by the method of Sjollema (1963).

A plastic funnel with a narrow stem, cut at right angles, was mounted exactly 2 cm above a piece of butter paper positioned on a horizontal table. A sieve with 16 mesh size was fixed to a shaker (100 shakings per minute). Powder sample was placed on the sieve and allowed to go through the funnel in a fine stream at a controlled speed, so as to form a conical heap. When the top of the powder heap touched the end of funnel stem, the powder stream was stopped

by switching off the shaker. The base of the powder heap was outlined with a pencil and powder was removed. After removing the powder, the outlined paper circle was cut out and weighed. The radius was calculated and the angle of repose estimated.

$$\text{Tan } \theta = \frac{h}{[\, r - \frac{1}{2} a \,]}$$

where, θ = angle of repose
h = height of stem base (2 cm)
r = radius of the base of powder heap
a = diameter of funnel stem

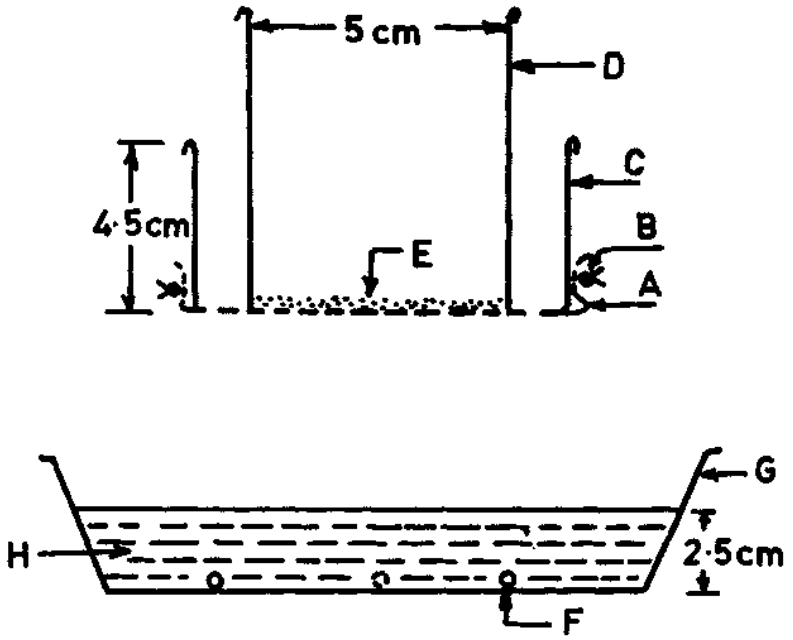
4.3.27 WETTABILITY

The method suggested by Muers and House(1962) was employed for testing wettability of kulfi mix powder with slight modification, in that the fabric used in the present investigation was a satin drill of 221.6 g/cm² having about 28 threads per cm wrap and 19 in the weft. A tray of 21.2 x 16.3 cm (length x breadth) was used instead of 20 x 15 cm.

A piece of satin-fabric measuring 10 x 10 cm was stretched over one end of the metallic can (open at both ends with 6.5 cm dia and 4.5 cm height) and fastened in position by a rubber band. Another open-end can (5 cm dia and 7 cm height) was placed centrally on the cloth (Fig. 1).

The tray was filled with distilled water at 40 ± 1°C to a height of 2.5 cm. A triangle made out of 0.4 cm thick glass rod with sides measuring 8 cm long was placed in the dish and served to prevent close contact of the cloth with the bottom of the dish.

With the two cans assembled, and cloth resting on outer can, 1 g of powder was transferred to the inner can and spread over the 6 cm circle of the cloth as evenly as possible with a soft sable hair brush. The inner can was then removed and the outer can lowered into the tray on to the glass triangle



A — SATIN FABRIC

B— RUBBER BAND

C — OUTER CAN (6·5 x 4·5 cm)

D — INNER CAN (5 x 7 cm)

E — POWDER SAMPLE (1gm)

F — TRIANGLE GLASS ROD (0·4 cm)

G — TRAY (21·2 x 16·3 cm)

H — WATER AT 40°C

FIG. 1 . WETTABILITY APPARATUS (ASSEMBLED)

and held in place, until the water level in the can ceased to rise. A stop watch was clicked as soon as the cloth touched the water and stopped when the powder got completely wet. The time taken for complete wetting of powder was recorded in seconds.

4.3.28 DISPERSIBILITY

Dispersibility of kulfi mix powder was determined by the method of Stone et al. (1954) as modified by Ingle (1971).

A brass bowl (subsequently called 'mixer', dimension 13 cm height, 13 cm top diameter and 24 cm inner diameter), fitted with an outlet of ½ inch diameter at the bottom was taken. To this, was attached a rubber tube fitted with a pinch cock. The mixer was clamped in such a way that it could be raised or lowered. Four hundred ml of distilled water at 40°C was placed in the mixer and 52 g of powder transferred to the surface of water. Stirring was done at 400 rpm for 20 sec. The fluid was then sieved through 72 mesh and volume made to 500 ml with distilled water. This was, thereafter, tested for total solids content by taking 10 ml of the diluted solution in a previously weighed aluminium dish and evaporated to dryness as per the method described in ISI method (SP:18 - 1981). The weight of solid multiplied by 50 gave the dispersibility in grams.

4.3.29 SOLUBILITY INDEX

The method described in ISI:SP:18 (1981) was followed for the determination of solubility index of kulfi mix powder. Fourteen grams of the powder was reconstituted in 100 ml of distilled water. The sediment obtained from 50 ml by centrifugation of reconstituted product was measured and results expressed in millilitres.

4.3.30 WATER ACTIVITY (a_w)

Water activity of kulfi mix powder was measured at 30°C using a water activity unit supplied by Rotronic Instrument Corporation (Hytington, New York). instrument was warmed up for 30 min before actual use. Kulfi mix powder peoples were filled up to the brim of the plastic cup supplied by the manufacturer. The cup was placed into the equilibration chamber and the lever intened to make the chamber air tight. As the sample reached a state of equilibrium (indicated by ERH and temperature indicator lamps), the per cent equilibrium Relative Humidity (ERH) and corresponding temperature readings were placed directly from the digital display. Normally the time required for the peoples to reach equilibrium varied between 20 and 30 min. ERH values were inverted into water activity using the following formula:

$$a_w = \frac{\text{Per cent ERH}}{100}$$

4.3.31 ELECTROPHORESIS

Differently heat treated kulfi mix samples were preserved after freeze Paying for electrophoretic studies. Freeze dried kulfi mix was used for electrophoresis following the method of deJong (1975) using the Metrex gel electrophoretic apparatus (disc type).

Gel buffer was prepared by dissolving 46 g Tris in one litre distilled water and pH of the buffer solution adjusted to 8.9 using a few drops of conc. hydrochloric acid. Gel solution was prepared by dissolving 54 g urea, 14 g Vancgum-41 and 0.2 ml N,N,N',N'-tetramethyl ethylene diamine (TEMED) in gel Buffer and the volume was made upto 200 ml. Electrode buffer was prepared by Dissolving 0.7 g Tris and 2.9 g glycine in one litre distilled water (pH 8.5). Example buffer was prepared by dissolving 8 M urea in electrode buffer.

4.3.31.1 Preparation of Sample

Fat was extracted from samples using a solvent mixture containing petroleum ether and chloroform (1:1) with vigorous shaking for 15 min. The solvent layer was decanted and another extraction made similarly. Defatted kulfi mix powder samples were pressed between two filter papers and allowed to dry overnight. One hundred mg of sample was dissolved in 10 ml of buffer. One ml of the prepared sample was delivered into a test tube and two drops each of bromophenol blue and mercaptoethanol added.

4.3.31.2 Preparation of Gel Tubes

The clean and dry glass tubes were arranged in a stand. Thirty ml of gel solution and 30 mg of ammonium persulphate were mixed thoroughly and quickly in a 50 ml beaker and poured immediately into gel tubes with the help of a clean, dry syringe avoiding entrapment of air bubbles. Gel tubes were left overnight for polymerization after addition of few drops of distilled water on the top of each tube.

4.3.31.3 Electrophoretic Run

Electrode buffer precooled to 4°C was filled in both top and bottom chambers of electrophoresis apparatus. Gel tubes were charged with aliquots of protein sample equivalent to 50 ug and 0.10 ml of 8 M urea added. The electrophoresis apparatus with gel tubes was placed in a refrigerated chamber at 10-12°C for 2 hr with an electric supply of 8 volts per tube. After completion of the run, gel tubes were dismantled and gels removed carefully with the help of a syringe. The raw buffalo skim milk sample served as a control.

4.3.31.4 Gel Staining and Destaining

The staining solution was prepared by dissolving 0.10 g of amido black dye in a solution containing 25 parts methanol, 65 parts water and 10 parts

acetic acid. Gels were stained by dipping, excess dye washed in distilled water and destained with 7.0 per cent acetic acid solution till clear bands appeared.

4.4 MICROBIOLOGICAL METHODS

4.4.1 SAMPLE COLLECTION

A total number of 60 kulfi samples were aseptically collected from 20 different retail outlets (10 each from Karnal and Delhi markets). Approximately 40 to 50 g of the samples were transferred to sterile screw cap MacCartney bottles with the help of a sterile (alcohol flamed and cooled) spatula. The sample bottles were transported to the laboratory in refrigerated condition in an insulated ice-box containing salt and ice mixture (1:1) and tested within 10 to 12 h of collection.

4.4.2 TOTAL VIABLE COUNT

Total number of viable bacteria in kulfi and kulfi mix powder were enumerated as per the method mentioned in ISI:SP:18 (1980) using standard Tryptone Glucose Yeast Agar. Inoculated plates were incubated at 37°C for 48 hr. The averages of the duplicate plates showing 30 to 300 colonies were calculated and expressed as the number of organisms per g of the sample.

4.4.3 COLIFORM COUNT

Coliform counts in kulfi and kulfi mix powder samples were made as per the method described in ISI:SP:18 (1980) using Eosine Methylene Blue Agar. The plates were incubated at 37°C for 48 hr.

4.4.4 RAPID COLIFORM TEST

Rapid coliform test of kulfi and kulfi mix powder was carried out according to the procedure of Singh and Sinha (1981) with slight modifications as suggested by Shrestha (1985). Eleven g of sample was mixed with 99 ml of

phosphate buffer (IS: 1479-1962). Hundred ml of the prepared sample was centrifuged at 4,000 rpm for 20 min followed by decantation of 95 ml of supernatant and mixing 5 ml of the bottom layer with equal amount of double strength MacConkey Broth. From the mixed sample, 1 ml aliquot was transferred to 100 x 6 mm tubes in duplicate, followed by 0.5 ml agar (1 per cent, w/v). The test tubes were incubated at 37°C and the time for appearance of gas bubbles at the junction of the aliquot mixture and soft agar noted at 30 min interval. The control sample was also run simultaneously with the addition of 1 to 2 drops of formalin.

4.4.5 STAPHYLOCOCCAL COUNT

The staphylococcal counts in the samples of kulfi and kulfi mix powder were determined according to the standard method (APHA, 1978) on S-110 agar (Chapman, 1946). 0.1 ml quantities of appropriate dilutions were streaked on S-110 agar in duplicate with the help of a sterile (alcohol flamed) glass rod bent at 45° angle. The plates were incubated at 37°C for 48 hr.

4.4.6 THERMOSTABLE DEOXYRIBONUCLEASE (TDNase) TEST

Kulfi and kulfi mix powder samples were screened for the preformed staphylococcal TDNase. Staphylococcal TDNase was first extracted from the samples using the method of Tatini et al. (1976) with slight modification. Extraction was carried out at pH 3.5 instead of pH 4.5 to rule out the possibility of extraction of non-staphylococcal TDNase at the former pH (Batish et al., 1984). TDNase activity was determined by metachromatic agar diffusion method of Lachica et al. (1971). The modified method was as follows:

Fifty g of sample was blended with 100 ml of distilled water and the pH was adjusted to 3.5 with 1 N HCl. The prepared sample was centrifuged (Model DAMON/IEC B-20A) at 20,000 x g for 15 min at 5°C. The supernatant fluid was

collected and 3 M TCA added followed by centrifugation at 20,000 x g for 15 min at 5°C. pH of the precipitate was adjusted to 9.0 with Tris buffer and the extract boiled for 15 min and cooled. Toludine Blue DNA Agar medium (Lachica et al., 1971) was adjusted to pH 9.0 and poured into 95 mm diameter petri dish. Agar plates were stored at 5-7°C until further use. Seven mm wells were made in each plate and 0.1 ml TDNase extracts gently transferred to each well. The plates were incubated for 4 to 5 hr at 37°C. Development of pink zones around the wells was a positive indication of the presence of TDNase. Sterile brain heart infusion (BHI) broth and distilled water were used as negative controls.

4.4.7 YEAST AND MOULD COUNT

Potato Dextrose Agar medium was used to determine the yeast and mould counts in kulfi and kulfi mix powder as per the standard method (APHA, 1978). Before pouring plates, the agar medium was acidified to pH 3.5 with sterile 10 per cent tartaric acid solution. Appropriate dilutions were plated in duplicate, incubated at 22°C for 3-5 days and colonies counted.

4.5 MICROSTRUCTURE

All the microstructure studies were conducted on a Hitachi Scanning Electron Microscope (S-405A) supplied by M/s. Hitachi Co., Japan.

4.5.1 VISUALIZATION OF ICE CRYSTALS

The procedure outlined by Buyong and Fennema (1988) was followed to determine the size and shape of ice crystals in frozen kulfi. A drop of experimental kulfi mix was placed on a microscope slide covered length wise with a strip of double-sided Scotch tape. Two other slides, each elevated by placement of four cover slips, were placed parallel to, and on both sides of the first slide. A fourth slide, placed on the edge with the long axis horizontal and at right angle to the sample slide was allowed to rest on the two flanking

slides and then drawn across the drop of sample so that the smear obtained had a thickness of 1 mm.

Drops of water surrounded by grease were placed on the sample slide near the smear to prevent the sample from drying during storage. Small rectangular pieces of glass were positioned in each end of the sample slide as support for a cover slide. The cover slide was elevated sufficiently so that it did not touch the sample. Stop lock grease was used to cause the glass pieces to stick together. Each such assembly was wrapped twice with Saran Wrap and stored at -12 ± 2°C for two durations, viz., 2 h and 7 days. This temperature is at times encountered during distribution and storage at the retail and home levels.

At the end of each storage period, assemblies were removed, unwrapped and freeze-dried using Model 10-MR-TR, Virtis Co. Inc., New York for 24 hr. The condenser temperature of -50°C and a vacuum of 0.05 Torr or less. After 24 hr, a section of the double-sided scotch tape along with the attached dried specimen was carefully removed from the slide and mounted on the specimen stubs of the scanning electron microscope and the samples later gold coated.

4.5.2 MICROSTRUCTURE OF KULFI MIX POWDER

The samples were prepared as per the procedure described by Buma and Henstra (1971a). Glue was extracted from cellophane tape by dissolving it in chloroform. One drop of this solution was placed on the metal stab. As soon as the chloroform got evaporated, some powder was sprinkled over the residual layer of glue by means of a fine stable hair brush. The excess particles were removed by tapping and gentle draft of air. Chopping of particles was done using a sharp blade under a field microscope for revealing the internal structure of the particles.

4.5.3 SPECIMEN COATING

All the specimen fixed on the metal stab were gold coated in an Eiko-1B-3 ion coater (supplied by M/s. Eiko Engineering Co., Japan) in a vacuum of 0.05 Torr by passing an ion current of 5 mA for 5 minutes.

4.5.4 VIEWING

The gold coated samples were viewed under scanning electron microscope (SEM) after adjusting a proper working distance, aperture size and tilt of the specimen as per the instructions of the equipment manufacturer. Samples were scanned at an accelerated voltage of 25 KV using secondary electron mode. The observations were recorded on ORWO black and white 55 NP 35 mm perforated film with the help of attached camera assembly.

4.6 SENSORY EVALUATION

Fresh kulfi and kulfi mix samples prepared from reconstituted kulfi mix powder were subjected to sensory evalation during the course of product development and storage studies. Test samples of kulfi along with control samples prepared from standardized formulation developed in the first phase of these investigations were served to trained panel of 7 judges selected from Dairy Technology Division. Scoring of kulfi samples was done on a 100 points score card (Annexure I) distributed over flavour-50; body and texture-35; colour and appearance-10 and melting quality-5. Scoring for dried mix as such was done on a 9-point hedonic scale with a score of 9 representing excellent and 1 as poor (Annexure II).

4.7 COST CALCULATIONS

The cost of raw buffalo milk at the dairy dock was taken at the rate of Rs.5 per litre. This price is higher than the prevailing average rate, being paid to milk producers by the Haryana Dairy Co-operative Federation (Rs.75 per

kg fat in milk). The expenditure on account of utilities, labour, laboratory expenses and packaging materials was calculated on the prevailing rates for each item generally used to Institute Dairy Plant. The depreciation on capital investment (building, equipment, machinery, etc.) was charged on standard rates. The interest on operating expenses and capital investment was charged at the rate of 18 per cent which is the prevailing bank rate for commercial loan.

4.8 TEST MARKETABILITY OF PRODUCT

Kulfi mix powder was reconstituted to prepare kulfi which was offered for sale at Institute's Milk Parlour, keeping the weight per piece to about 100 g. The consumers were supplied with a product rating card (Annexure-III) and their response obtained for overall acceptability, price and frequency of purchase with any other special remarks.

4.9 STATISTICAL ANALYSIS

The data were analysed for analysis of variance (ANOVA) and standard deviation (SD) according to the procedure recommended by Snedecor and Cochran (1967). Unpaired 't' test was also carried out to ascertain the difference between Karnal and Delhi market sample of kulfi.

CHAPTER 5

RESULTS AND DISCUSSION

5. RESULTS AND DISCUSSION

The most preferred quality attributes of kulfi sold in the markets and reasons for popularity were first identified on the basis of the market survey. The results were used as a reference point for product formulation and optimization of processing parameters for commercial manufacture of kulfi. Standardization of spray drying technology for the production of kulfi mix powder comprised the second phase of the investigation. The changes in the physico-chemical and sensory characteristics as well as those occurring during storage and extension of shelf life of dried product formed the integral part of the studies. The results have been tabulated and interpreted with the help of statistical methods. The results are supported with appropriate illustrations and conclusions drawn under the different headings.

5.1 SURVEY OF MARKET SAMPLES OF KULFI

5.1.1 TRADE PRACTICES IN KULFI PREPARATION

At present, kulfi is prepared by halwais in small quantities involving 15 to 40 kg milk per lot. The method of preparation varies from shop to shop. The different methods used for kulfi making have been presented in Fig. 2. Halwais usually prefer buffalo milk for kulfi making. Milk after filtration through muslin cloth, is boiled and concentrated in a large open pan (karahi) followed by addition of sugar (Process A) and then cooled to room temperature. In another method which is generally followed in Delhi market (Process B), milk is heated at 85-90°C. As the milk evaporates slowly, a skin (malai) or clotted cream is formed on the top surface. Malai is removed after each 5 to 7 min until sufficient quantity is obtained. The remaining portion of milk is boiled

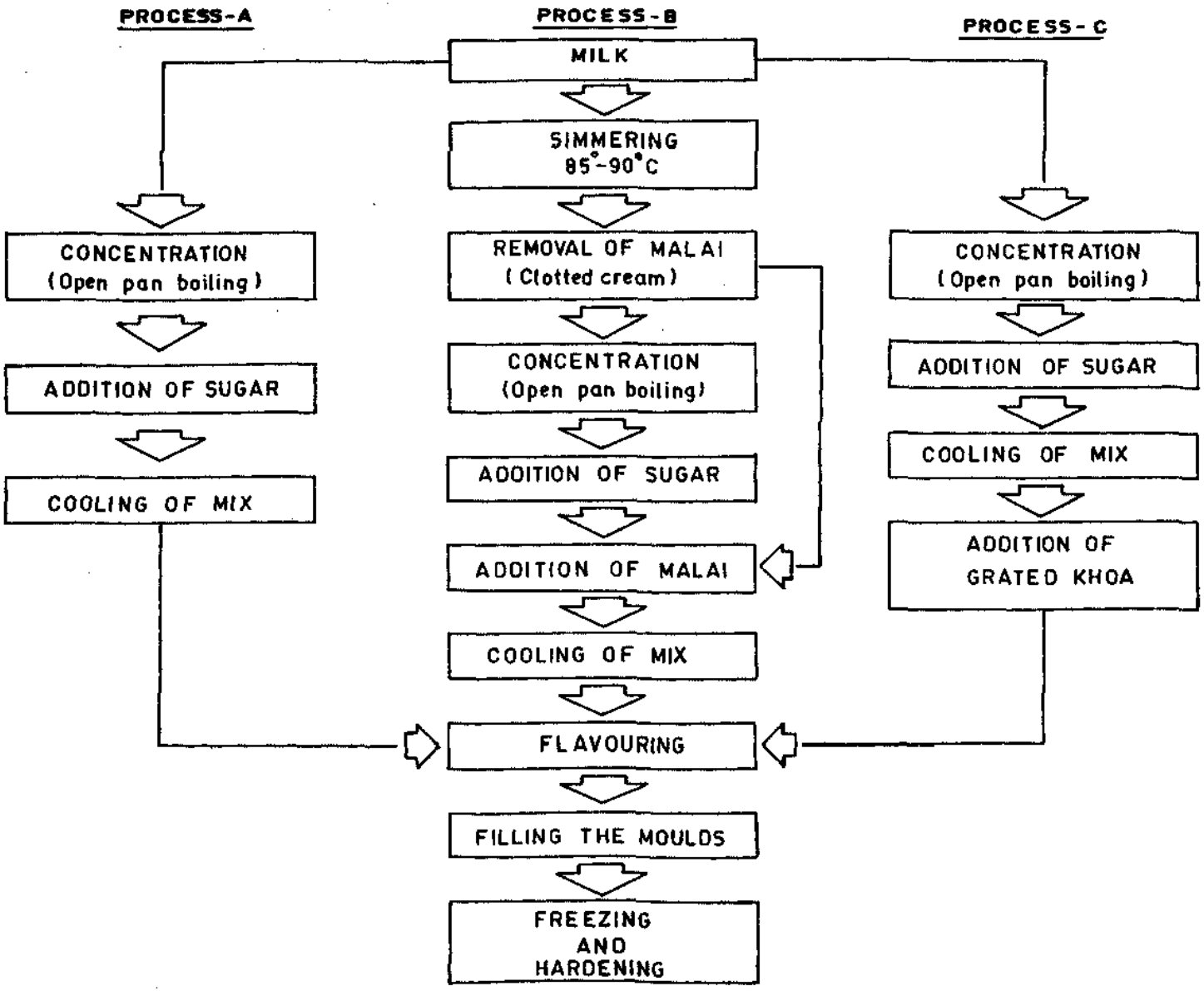


FIG. 2. PROCESS FLOW FOR PREPARATION OF KULFI IN DIFFERENT MARKET

to achieve the required concentration. This step is followed by addition of sugar and subsequently, the layers of clotted cream are returned to the sweetened concentrated milk. The mixture is then cooled to room temperature. At times, grated khoa is added to the mix as obtained in Process A to increase both the total solids content and cooked flavour in kulfi (Process C).

In all the processing methods, the mix after cooling is added with natural or synthetic flavours like essence of rose, keora (pandanus or screw pine) or powdered cardamom seeds. Mix is then filled into triangular, conical or cylindrical moulds usually made of aluminium, plastic and even earthen ware (Plate 1). The moulds are closed either by placing a lid and sealing the edges with wheat dough or by screw cap fixed in place with a rubber band. Moulds are thereafter immersed in a large earthen pot (matka) containing ice and salt mixture. The freezing process is carried out by constant to-and-fro motion of the earthen pot. Moulds with frozen kulfi are transferred to a deep freeze or kept in the salt and ice mixture until sold. The product is served as such or topped with falooda (an indigenous vermicelli like product) and top dressed with keora or rose flavoured sugar syrup.

5.1.2 CHEMICAL COMPOSITION OF MOST SELLING KULFI SAMPLES

A total number of 60 samples (30 each from reputed retail outlets of Karnal and Delhi) were analysed for gross chemical composition (Tables 6 and 7). The unpaired 't' test for kulfi samples collected from two markets is given in Table 8.

5.1.2.1 Total Solids Content

The total solids content in Karnal samples of kulfi varied from 33.95 to 43.16 with an average of 39.04 per cent (Table 8). Three samples out of 30 (retail outlet code No.1) drawn from Karnal market failed to meet the minimum

Table 6. Chemical composition of market samples of kulfi collected from Karnal

Retail outlet code	Constituents (per cent)					
	Total solids	Fat	Protein	Lactose	Sucrose	Ash
1	33.95-34.21 (34.09±0.11)	6.56-6.72 (6.63±0.07)	4.33-4.44 (4.38±0.05)	5.74-5.82 (5.77±0.03)	15.91-15.95 (15.94±0.02)	1.37-1.43 (1.40±0.02)
2	36.42-36.58 (36.50±0.07)	7.31-7.65 (7.50±0.14)	5.08-5.15 (5.12±0.03)	6.75-6.97 (6.68±0.09)	15.36-15.67 (15.56±0.14)	1.38-1.51 (1.46±0.06)
3	38.53-38.79 (38.67±0.11)	7.17-7.37 (7.28±0.08)	5.44-5.63 (5.53±0.08)	7.31-7.43 (7.37±0.05)	16.73-16.48 (16.87±0.10)	1.57-1.68 (1.62±0.04)
4	42.54-42.78 (42.68±0.10)	11.47-11.62 (11.53±0.06)	6.51-6.63 (6.58±0.05)	8.74-8.80 (8.77±0.02)	13.92-14.21 (14.05±0.12)	1.68-1.80 (1.75±0.05)
5	42.85-43.16 (42.98±0.13)	11.31-11.65 (11.49±0.14)	6.58-6.87 (6.72±0.12)	8.75-9.30 (8.99±0.23)	13.87-14.30 (14.10±0.18)	1.59-1.75 (1.68±0.07)
6	39.25-39.40 (39.34±0.06)	8.13-8.30 (8.21±0.07)	5.05-5.18 (5.12±0.05)	6.72-6.86 (6.80±0.06)	17.24-17.92 (17.63±0.26)	1.51-1.64 (1.58±0.05)
7	38.07-38.36 (38.24±0.12)	8.75-9.07 (8.93±0.13)	4.65-4.76 (4.71±0.04)	6.18-6.33 (6.27±0.06)	16.57-16.89 (16.72±0.13)	1.58-1.64 (1.61±0.02)
8	40.50-40.72 (40.61±0.09)	10.07-10.31 (10.20±0.10)	5.76-5.89 (5.82±0.05)	7.60-8.11 (7.85±0.19)	14.92-15.26 (14.52±0.14)	1.57-1.67 (1.62±0.04)
9	39.55-39.84 (39.70±0.11)	10.42-10.58 (10.51±0.06)	5.68-5.84 (5.76±0.06)	7.58-7.67 (7.63±0.05)	13.95-14.36 (14.17±0.17)	1.59-1.68 (1.63±0.04)
10	37.51-37.74 (37.60±0.09)	9.12-9.35 (9.23±0.09)	4.95-5.17 (5.07±0.09)	6.63-6.94 (6.79±0.13)	14.78-15.10 (14.98±0.14)	1.49-1.56 (1.53±0.05)

Figures in the parentheses represent means of three replicates with standard deviation (S.D.)

Table 7. Chemical composition of market samples of Kulfi collected from [illegible]

Retail outlet code	Constituents (per cent)					
	Total solids	Fat	Protein	Lactose	Sucrose	Ash
1	48.92-49.13 (48.02±0.09)	13.73-13.87 (13.80±0.06)	6.15-6.37 (6.25±0.09)	8.20-8.51 (8.33±0.13)	18.65-18.93 (18.78±0.11)	1.76-1.93 (1.86±0.07)
2	46.15-46.31 (46.23±0.06)	10.92-11.06 (11.00±0.06)	6.48-6.63 (6.56±0.06)	8.62-8.90 (8.79±0.12)	18.23-18.39 (18.31±0.06)	1.51-1.63 (1.57±0.05)
3	44.28-44.44 (44.37±0.07)	11.73-11.91 (11.83±0.07)	6.60-6.74 (6.68±0.06)	8.78±8.95 (8.87±0.07)	15.20-15.41 (15.31±0.09)	1.61-1.75 (1.68±0.06)
4	45.30-45.52 (45.42±0.17)	12.25-12.39 (12.32±0.06)	6.38-6.47 (6.43±0.04)	8.49-8.66 (8.57±0.07)	16.47-16.69 (16.59±0.09)	1.48-1.54 (1.51±0.02)
5	45.40-45.70 (45.56±0.12)	12.07-12.31 (12.19±0.10)	6.49-6.60 (6.55±0.04)	8.69-8.82 (8.76±0.05)	16.31-16.53 (16.43±0.09)	1.59-1.68 (1.63±0.04)
6	47.50-47.77 (47.65±0.11)	11.70-12.01 (11.87±0.13)	5.85-6.00 (5.94±0.06)	7.84-8.02 (7.92±0.07)	20.21-20.46 (20.34±0.10)	1.54-1.62 (1.58±0.03)
7	39.40-39.66 (39.54±0.12)	11.41-11.63 (11.53±0.09)	5.15-5.26 (5.21±0.04)	6.84-6.92 (6.88±0.03)	14.37-14.59 (14.49±0.09)	1.40-1.47 (1.43±0.03)
8	41.51-41.73 (41.63±0.09)	10.07-10.30 (10.20±0.10)	5.26-5.43 (5.34±0.07)	7.00-7.18 (7.10±0.07)	17.40-17.62 (17.52±0.09)	1.44-1.50 (1.47±0.02)
9	42.28-42.43 (42.36±0.06)	10.58-10.86 (10.73±0.11)	6.07-6.20 (6.14±0.05)	8.10-8.24 (8.17±0.06)	15.68-15.89 (15.79±0.09)	1.49-1.58 (1.53±0.04)
10	43.52-43.73 (43.63±0.09)	11.21-11.42 (11.31±0.09)	5.77-5.92 (5.86±0.06)	7.70-7.96 (7.85±0.11)	16.92-17.10 (17.00±0.07)	1.58-1.64 (1.61±0.02)

Figures in the parentheses represent means of three replicates with S.D.

legal requirement in terms of total solids (P.F.A. 1976). Delhi samples of kulfi carried higher total solids content ranging from 39.40 to 49.13 per cent (average 44.54 per cent) than the Karnal samples. The unpaired 't' test of these variations was found to be significant at $P < 0.05$ (Table 8). The variations in the TS in kulfi samples could largely be attributed to the differences in the chemical composition of milk, extent of milk solids concentration, percentage of sugar added, and method of preparation. Thatti et al. (1972) also reported wide variations in TS of kulfi in Bombay market ranging from 40.2 to 54.5 with an average of 46.80 per cent.

A small variation in TS from 36.0 to 41.4 in market samples collected from Bangalore and still narrow variation from 37.5 to 39.5 per cent in the samples collected from Hisar was reported by Yerriswamy et al. (1983) and Yadav (1990) respectively.

5.1.2.2 Fat Content

Wide variations in fat content of kulfi were observed within the markets. Fat in Karnal samples ranged from 6.56 to 11.5 (average 9.15 per cent) and in Delhi samples from 10.07 to 13.87 (average 11.68 per cent). These variations were subjected to unpaired 't' test which indicated that the market significantly ($P < 0.05$) influenced the fat content in kulfi. Thatti et al. (1972) also reported large variations in fat content in the market samples of kulfi (10.05 to 25.4 with an average of 18.0 per cent) collected from Bombay. It is surprising to note that Rao (1978) found exceedingly low fat content in Karnal samples of kulfi (3.4 to 6.5 with an average of 5.1 per cent).

All the kulfi samples collected from Delhi fell within the prescribed legal limits of PFA (1976) in respect of fat. However, 18 out of 30 kulfi samples in Karnal city (retail outlet code 1, 2, 3, 6, 7 and 9) were found to be deficient in fat content. Yadav (1990) found all the kulfi samples from

Hisar city to carry low fat content ranging between 6.3 and 7.0 per cent. Use of either partially skimmed milk or removal of malai while concentrating the milk could lead to such low fat in kulfi. None of the kulfi traders understood the meaning of standardization or significance of quality control.

Table 8. Unpaired 't' test for chemical composition of kulfi collected from Karnal and Delhi markets

Market	Constituents (per cent)					
	Total solids	Fat	Protein	Lactose	Sucrose	Ash
Av. values for Karnal kulfi	39.04	9.15	5.48	7.31	15.51	1.57
Av. values for Delhi kulfi	44.54	11.68	6.09	8.12	17.05	1.59
't' values	4.173*	3.999*	2.139*	1.541	2.403*	0.038

* Significant at $P < 0.05$

5.1.2.3 Protein Content

The protein content in kulfi varied from 4.33 to 6.87 with an average of 5.48 per cent in Karnal samples and from 5.15 to 6.74 with an average of 6.09 per cent in Delhi samples. This would indicate that variations in protein are influenced by the market significantly ($P < 0.05$). These variations can be caused by the initial composition of milk, the degree of TS concentration and the mix formulation. Thatti et al.(1972) also reported much wider variation in protein content of kulfi (3.10 to 5.80 with an average of 4.30 per cent) than that found in the present study. Yerriswamy et al. (1983) obtained a narrow variation of 4.60 to 5.00 per cent in protein which would indicate that the base material had fairly uniform chemical composition.

5.1.2.4 Lactose Content

The lactose content was found to vary considerably between and within the markets. Karnal samples were found to show fairly wide variations in lactose (5.74 to 9.30, average 7.31 per cent) as compared with Delhi samples in which the values ranged from 6.84 to 8.95 with an average of 8.12 per cent. The high values of lactose content in some of the samples of kulfi were attributed to the reported addition of corn syrup and fruit juices which increase the concentration of reducing sugar (Thatti et al., 1972).

5.1.2.5 Sucrose Content

Sucrose is the main ingredient that can be considerably varied in kulfi. About 35 to 45 per cent of the total solids in kulfi were contributed by sucrose. Karnal samples of kulfi were found to contain slightly lower sucrose (average 15.51 per cent) as compared with Delhi samples where the average was 17.05 per cent. Unpaired 't' test indicated that the markets exert significant influence ($P < 0.05$) on sucrose content of kulfi. The sucrose content in market samples of Bombay kulfi varied between 10.9 and 16.0 per cent with an average of 14.4 per cent (Thatti et al., 1972). Rao (1978) also reported wide variations in sucrose content of kulfi (13.0 to 20.0 per cent). Sucrose sells at a lower price than the milk solids and its increased amount in kulfi brings larger profits to itinerant traders.

5.1.2.6 Total Ash Content

The total ash content in kulfi samples from Karnal varied between 1.37 to 1.80 per cent and in Delhi samples from 1.40 to 1.93 per cent. About the same ash content in Hisar samples of kulfi (1.4 per cent) was reported by Yadav (1990). Higher ash content, despite comparatively lower total solids content in Karnal sample than its Delhi counterparts, could be contributed by crude sugar

(Khandsari) which contains about 0.7 per cent ash. Dust and dirt particles contaminating the milk and resultant product at various stages of manufacture would also lead to increased total ash content in market samples of kulfi.

5.1.2.7 Starch Test

Interestingly, none of the samples gave a positive starch test. Thatti et al. (1972) found the presence of starch in few samples of kulfi. It may seem logical to believe that the public health authorities have become more vigilant now and the practice of adding starch in the preparation of kulfi has become a thing of past.

It may be concluded that even the most popular samples of kulfi manufactured and sold in the markets had varied chemical composition, some of which fell below the prescribed legal requirement in terms of TS and fat. These findings make a strong case for organized production of kulfi to cater to regional demands on large scale.

5.1.3 CHARACTERIZATION OF PHYSICO-CHEMICAL PROPERTIES OF MARKET SAMPLES OF KULFI

The physico-chemical properties of kulfi samples collected from Karnal and Delhi markets have been depicted in Tables 9 and 10 respectively.

5.1.3.1 Titratable Acidity

The titratable acidity of kulfi samples sold in Karnal and Delhi markets ranged from 0.21 to 0.28 and 0.27 to 0.36 per cent respectively. Higher values of titratable acidity in Delhi samples could be attributed to higher total solids in kulfi. Yerriswamy et al. (1983) have reported very low titratable acidity in market samples of kulfi (0.18 to 0.22 per cent) containing 36.0 to 41.2 per cent total solids. These workers used direct titration method which gives low acid values.

Table 9. Physico-chemical properties of market samples of kulfi collected from Karnal

Retail outlet code	Acidity (% LA)	pH	p-DMAB reactivity (absorbance at 545 nm)	Relative viscosity	Surface tension (dynes/cm)	Melt down (ml/30 min)
1	0.21-0.22 (0.21±0.004)	6.52-6.51 (6.52±0.004)	0.031-0.034 (0.033±0.001)	1.42-1.46 (1.44±0.016)	48.5-49.3 (48.87±0.33)	25.0-25.3 (25.16±0.12)
2	0.22-0.23 (0.23±0.004)	6.50-6.49 (6.49±0.004)	0.035-0.037 (0.036±0.009)	1.62-1.66 (1.64±0.017)	48.4-48.7 (48.53±0.12)	25.7-26.0 (25.83±0.12)
3	0.23-0.24 (0.24±0.004)	6.48-6.46 (6.47±0.009)	0.037-0.041 (0.039±0.001)	1.64-1.68 (1.66±0.016)	47.6-47.9 (47.76±0.12)	26.2-26.7 (26.46±0.20)
4	0.27-0.28 (0.28±0.004)	6.40-6.38 (6.39±0.008)	0.048-0.053 (0.050±0.002)	1.89-1.92 (1.90±0.012)	45.2-45.4 (45.3±0.08)	28.5-29.0 (28.75±0.20)
5	0.27-0.28 (0.27±0.004)	6.39-6.37 (6.38±0.008)	0.051-0.055 (0.053±0.001)	1.92-1.97 (1.95±0.020)	44.8-45.1 (44.96±0.12)	30.0-30.2 (30.13±0.09)
6	0 23-0.24 (0.23-0.004)	6.47-6.45 (6.45±0.009)	0.036-0.039 (0.037±0.001)	1.78-1.82 (1.80±0.02)	47.5-47.8 (47.63±0.12)	26.5-27.0 (26.76±0.20)
7	0.24-0.25 (0.24±0.004)	6.46-6.43 (6.44±0.012)	0.034-0.036 (0.035±0.002)	1.76-1.81 (1.78±0.02)	47.6-48.0 (47.8±0.16)	26.4-26.8 (26.63±0.17)
8	0.26-0.27 (0.27±0.004)	6.41-6.39 (6.40±0.009)	0.039-0.043 (0.041±0.001)	1.78-1.81 (1.79±0.01)	45.6-46.1 (45.86±0.20)	28.1-28.5 (28.33±0.17)
9	0.26-0.27 (0.26±0.004)	6.42-6.40 (6.41±0.009)	0.038-0.041 (0.039±0.001)	1.79-1.83 (1.80±0.02)	45.5-45.9 (45.73±0.17)	27.2-27.5 (27.36±0.12)
10	0.23-0.24 (0.24±0.004)	6.47-6.44 (6.46±0.012)	0.037-0.039 (0.038±0.009)	1.63-1.65 (1.64±0.012)	48.0-48.2 (48.06±0.09)	26.0-26.3 (26.16±0.12)

Figures in the parentheses represent means of three replicates with S.D.

Table 10. Physico-chemical properties of market samples of kulfi collected from Delhi

Retail outlet code	Acidity (% LA)	pH	p-DMAB reactivity (absorbance at 545 nm)	Relative viscosity	Surface tension (dynes/cm)	Melt down (ml/30 min)
1	0.35-0.36 (0.36±0.004)	6.28-6.26 (6.27±0.009)	0.081-0.085 (0.083±0.001)	2.24-2.32 (2.29±0.03)	44.7-45.1 (44.9±0.16)	20.0-20.5 (20.27±0.20)
2	0.32-0.33 (0.33±0.004)	6.34-6.32 (6.33±0.008)	0.075-0.079 (0.077±0.001)	2.12-2.16 (2.14±0.02)	45.3-45.6 (45.43±0.12)	22.5-22.8 (22.66±0.12)
3	0.32-0.33 (0.33±0.004)	6.35-6.33 (6.34±0.009)	0.074-0.078 (0.076±0.001)	2.15-2.19 (2.17±0.02)	44.9-45.3 (45.06±0.17)	23.6-24.0 (23.83±0.17)
4	0.33-0.34 (0.34±0.004)	6.32-6.30 (6.31±0.004)	0.075-0.080 (0.078±0.002)	2.17±2.24 (2.21±0.03)	45.2-45.5 (45.33±0.12)	23.1-23.6 (23.36±0.20)
5	0.33-0.34 (0.33±0.004)	6.32-6.31 (6.32±0.004)	0.078-0.082 (0.080±0.001)	2.22-2.27 (2.25±0.02)	44.8-45.2 (44.96±0.17)	23.0-23.4 (23.20±0.14)
6	0.34-0.35 (0.35±0.004)	6.30-6.28 (6.29±0.009)	0.068-0.073 (0.070±0.002)	2.21-2.26 (2.24±0.02)	45.7-46.1 (45.90±0.16)	20.8-21.4 (21.20±0.28)
7	0.27-0.28 (0.28±0.004)	6.41-6.38 (6.39±0.012)	0.058-0.062 (0.059±0.001)	1.87-1.92 (1.89±0.02)	46.3-46.8 (46.53±0.20)	26.4-26.8 (26.63±0.17)
8	0.27-0.28 (0.27±0.004)	6.40-6.38 (6.39±0.009)	0.056-0.059 (0.057±0.001)	1.85-1.89 (1.87±0.02)	46.9-47.3 (47.13±0.17)	27.4-27.9 (27.60±0.22)
9	0.28-0.29 (0.28±0.004)	6.39-6.36 (6.37±0.012)	0.062-0.068 (0.065±0.002)	1.87-1.92 (1.90±0.02)	46.2-46.8 (46.50±0.24)	28.3-28.7 (28.50±0.16)
10	0.28-0.29 (0.29±0.004)	6.40±6.37 (6.38±0.012)	0.061-0.065 (0.063±0.001)	1.86-1.91 (1.89±0.02)	46.6-47.2 (46.86±0.25)	28.8-29.5 (29.13±0.29)

Figures in the parentheses represent means of three replicates with S.D.

5.1.3.2 pH

The pH of kulfi samples collected from Karnal and Delhi market ranged between 6.37 and 6.52, and 6.26 and 6.41 respectively. The lower pH values for Delhi samples could be due to higher milk solids content. Prolonged heat treatment of kulfi mix may also lead to increased titratable acidity and lower pH values (Yerriswamy et al., 1984). pH values of market samples of kulfi were reported to vary from 6.06 to 6.18 (Yerriswamy et al., 1983). These values are lower than those observed in the present findings.

5.1.3.3 p-DMAB Reactivity

The p-DMAB reactivity of kulfi within the same market and between the two markets varied significantly indicative of varying degree of heat treatments applied to kulfi mix before freezing. Delhi samples showed relatively higher p-DMAB values indicating greater degree of heat treatment applied to mix (Table 10). Measurement of p-DMAB reactivity is an indirect index of total reducing capacity of kulfi which would have a direct influence on the oxidative stability of proposed fat rich dried kulfi mix.

5.1.3.4 Relative Viscosity

The relative viscosity of kulfi samples collected from Karnal varied from 1.42 to 1.97. Such variations can be caused by the differences in total solids content (Yerriswamy et al., 1983) or the presence of stabilizers. Relative viscosity for Delhi samples of kulfi ranged between 1.85 and 2.32. This could have been caused by a cumulative action of increased solids and severity of heat treatment during concentration of milk by open pan method (Salooja, 1979). Aging of mix at low temperature (4-5°C) also increases the viscosity due to the solidification of butterfat and hydration of proteins (Arbuckle, 1986). However, aging is not a common practice in the preparation of kulfi.

5.1.3.5 Surface Tension

The surface tension of kulfi samples decreased with an increase in total milk solids. Perusal of Tables 9 and 10 would indicate that the surface tension values for Karnal and Delhi markets ranged from 44.8 to 49.3 and 44.7 to 47.2 dynes/cm respectively. Increased fat and MSNF contents were found to be associated with the reduction in surface tension of kulfi mix (Salooja, 1979).

5.1.3.6 Melt Down

The melt down of kulfi from Karnal and Delhi markets varied from 25.0 to 30.2 and 20.0 to 29.5 ml respectively (Tables 9 and 10). Melt down is dependent upon the nature of constituents, total solids of mix and processing conditions. In the present case, the gradual increase in the melt down for Karnal samples upto 43.0 per cent total solids (Table 6) could be due to increased lactose concentration which caused freezing point depression of the mix. In a situation where the amount of water frozen in kulfi for a given temperature decreased and the amount of water remaining unfrozen was more, the rate of melting was higher (Salooja, 1979). Further increase in total solids (Table 7), no doubt, could have depressed the freezing point further. The heavy and soggy texture of kulfi contributed by higher total solids was associated with increased melting resistance and the melt down decreased (Ashokraju et al., 1989).

5.3.1.7 Overrun

All the samples of kulfi from Karnal and Delhi were found to have no overrun. Yadav (1990) reported that weight of kulfi samples collected from Hisar city ranged from 818 to 860 g/lit. Differences were highly significant between sources, samples and interaction. The method of preparation of kulfi specially freezing could lead to air incorporation in the mix. Consumers,

however, do not seem to prefer any overrun in kulfi. The product is, therefore, sold on weight basis.

5.1.4 CHARACTERIZATION OF MICROBIOLOGICAL QUALITY OF MARKET SAMPLES OF KULFI

Kulfi samples collected from Karnal and Delhi markets were found to be heavily contaminated with various types of microorganisms particularly the staphylococci, coliform and yeast and moulds (Tables 11 and 12). The insanitary practices associated with the preparation and subsequent handling of the product cause this problem.

5.1.4.1 Total Viable Counts (TVC)

The TVC in kulfi collected from Karnal varied between 41 x 10^2 and 92 x 10^5 per g (Table 11) with an average of 17.15 x 10^5 per g (Table 13). Delhi samples also showed high incidence of TVC ranging from 37 x 10^3 to 87 x 10^5 (Table 12) with an average of 15.25 x 10^5 per g (Table 13). Most of the samples exceeded the maximum limit of 250,000 organisms per g fixed by Indian Standards (IS: 10501-1983). Rao (1978) also reported high TVC of 28 x 10^5/g in market samples of kulfi. Prolonged storage of kulfi mix at high ambient temperature before freezing and use of poor quality ingredients may lead to high microbial load. Batish et al. (1984) also reported very high TVC in kulfi which ranged between 17 x 10^4 and 66 x 10^8 with an average of 10 x 10^8 per g. Push cart samples of kulfi were generally inferior in microbiological quality.

5.1.4.2 Staphylococcal Counts

The results of the present study indicate that kulfi samples from Karnal and Delhi markets had a large population of staphylococci (Tables 11 and 12). Careless handling of kulfi mix and kulfi with bare hands leads to this problem. Significant differences ($P < 0.05$) were observed between the two markets studied (Table 13). A carry over effect of staphylococci organisms on skin and hands

Table 11. Microbiological quality of market samples of kulfi collected from Karnal

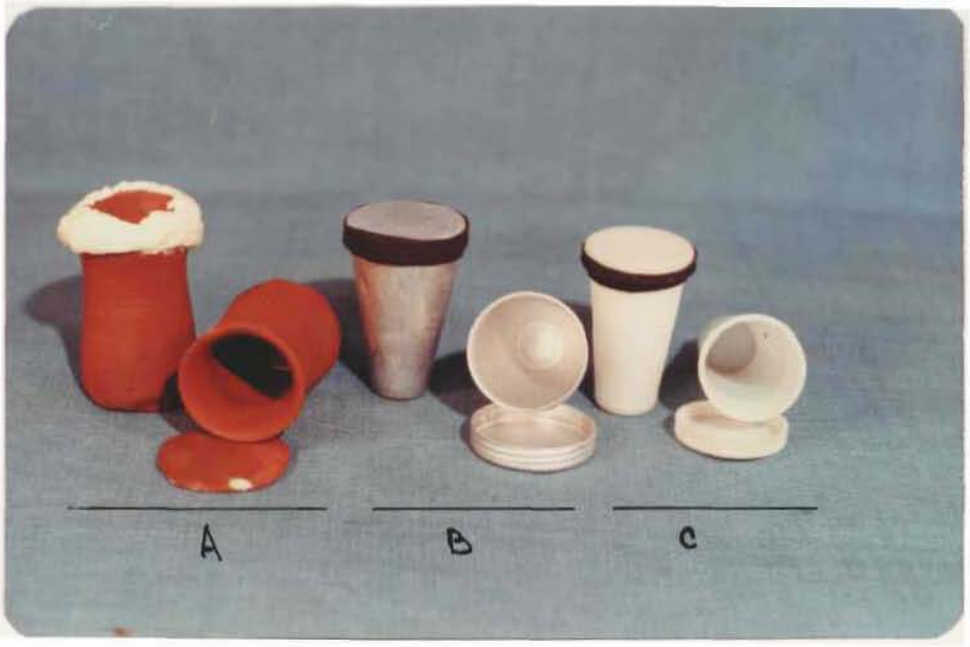
Retail outlet code*	Counts (per g)			
	TVC	Staphylococcal	Coliform	Yeast and Mould
1	$32x10^3$ - $16x10^4$ ($43.27x10^3$)	$23x10^3$ - $10x10^4$ ($6.46x10^4$)	$13x10^1$ - $28x10^1$ ($20.33x10^1$)	$6x10^1$ - $8x10^1$ ($6.66x10^1$)
2	$69x10^2$ - $15x10^3$ ($83.12x10^2$)	$15x10^4$ - $45x10^4$ ($30.00x10^4$)	$15x10^1$ - $24x10^1$ ($20.12x10^1$)	$6x10^1$ - $10x10^1$ ($7.66x10^1$)
3	$41x10^2$ - $52x10^3$ ($65.18x10^2$)	$39x10^5$ - $52x10^6$ ($22.86x10^6$)	$21x10^1$ - $35x10^1$ ($27.63x10^1$)	$13x10^1$ - $21x10^1$ ($17.33x10^1$)
4	$85x10^2$ - $78x10^3$ ($35.83x10^3$)	$42x10^4$ - $57x10^5$ ($23.30x10^5$)	$11x10^1$ - $14x10^1$ ($12.33x10^1$)	$19x10^1$ - $27x10^1$ ($23.66x10^1$)
5	$35x10^4$ - $61x10^5$ ($25.83x10^5$)	$65x10^3$ - $51x10^4$ ($22.06x10^4$)	$27x10^2$ - $35x10^2$ ($30.66x10^2$)	$24x10^1$ - $37x10^1$ ($29.65x10^1$)
6	$29x10^4$ - $35x10^5$ ($15.23x10^5$)	$27x10^2$ - $54x10^3$ ($20.80x10^3$)	$16x10^2$ - $39x10^2$ ($27.66x10^2$)	$25x10^1$ - $41x10^1$ ($34.00x10^1$)
7	$73x10^4$ - $68x10^5$ ($30.43x10^5$)	$81x10^3$ - $34x10^4$ ($18.03x10^4$)	$81x10^2$ - $97x10^2$ ($89.66x10^2$)	$21x10^2$ - $37x10^2$ ($29.00x10^2$)
8	$67x10^4$ - $89x10^5$ ($47.23x10^5$)	$38x10^2$ - $68x10^3$ ($26.23x10^3$)	$39x10^2$ - $48x10^2$ ($43.33x10^2$)	$9x10^2$ - $14x10^2$ ($11.33x10^2$)
9	$131x10^4$ - $92x10^5$ ($40.96x10^5$)	$15x10^3$ - $97x10^3$ ($53.00x10^3$)	$37x10^3$ - $41x10^3$ ($39.00x10^3$)	$11x10^2$ - $17x10^2$ ($14.66x10^2$)
10	$82x10^4$ - $15x10^5$ ($10.93x10^5$)	$19x10^3$ - $71x10^4$ ($25.93x10^4$)	$24x10^2$ - $31x10^2$ ($28.00x10^2$)	$18x10^2$ - $24x10^2$) ($20.66x10^2$)

Figures in the parentheses represent means of three replicates

Table 11. Microbiological quality of market samples of kulfi collected from Karnal

Retail outlet code*	Counts (per g)			
	TVC	Staphylococcal	Coliform	Yeast and Mould
1	32×10^{3} - 16×10^{4} (43.27×10^{3})	23×10^{3} - 10×10^{4} (6.46×10^{4})	13×10^{1} - 28×10^{1} (20.33×10^{1})	6×10^{1} - 8×10^{1} (6.66×10^{1})
2	69×10^{2} - 15×10^{3} (83.12×10^{2})	15×10^{4} - 45×10^{4} (30.00×10^{4})	15×10^{1} - 24×10^{1} (20.12×10^{1})	6×10^{1} - 10×10^{1} (7.66×10^{1})
3	41×10^{2} - 52×10^{3} (65.18×10^{2})	39×10^{5} - 52×10^{6} (22.86×10^{6})	21×10^{1} - 35×10^{1} (27.63×10^{1})	13×10^{1} - 21×10^{1} (17.33×10^{1})
4	85×10^{2} - 78×10^{3} (35.83×10^{3})	42×10^{4} - 57×10^{5} (23.30×10^{5})	11×10^{1} - 14×10^{1} (12.33×10^{1})	19×10^{1} - 27×10^{1} (23.66×10^{1})
5	35×10^{4} - 61×10^{5} (25.83×10^{5})	65×10^{3} - 51×10^{4} (22.06×10^{4})	27×10^{2} - 35×10^{2} (30.66×10^{2})	24×10^{1} - 37×10^{1} (29.65×10^{1})
6	29×10^{4} - 35×10^{5} (15.23×10^{5})	27×10^{2} - 54×10^{3} (20.80×10^{3})	16×10^{2} - 39×10^{2} (27.66×10^{2})	25×10^{1} - 41×10^{1} (34.00×10^{1})
7	73×10^{4} - 68×10^{5} (30.43×10^{5})	81×10^{3} - 34×10^{4} (18.03×10^{4})	81×10^{2} - 97×10^{2} (89.66×10^{2})	21×10^{2} - 37×10^{2} (29.00×10^{2})
8	67×10^{4} - 89×10^{5} (47.23×10^{5})	38×10^{2} - 68×10^{3} (26.23×10^{3})	39×10^{2} - 48×10^{2} (43.33×10^{2})	9×10^{2} - 14×10^{2} (11.33×10^{2})
9	131×10^{4} - 92×10^{5} (40.96×10^{5})	15×10^{3} - 97×10^{3} (53.00×10^{3})	37×10^{3} - 41×10^{3} (39.00×10^{3})	11×10^{2} - 17×10^{2} (14.66×10^{2})
10	82×10^{4} - 15×10^{5} (10.93×10^{5})	19×10^{3} - 71×10^{4} (25.93×10^{4})	24×10^{2} - 31×10^{2} (28.00×10^{2})	18×10^{2} - 24×10^{2}) (20.66×10^{2})

Figures in the parentheses represent means of three replicates


A
B
C

e
d
a
g
c
b
f

Plate 1 Types of kulfi moulds used for kulfi preparation

A - Earthen ware moulds

B - Anodized aluminium moulds

C - Plastic moulds

Plate 2 Thermostable DNase (TDNase) detection in kulfi samples

a to d - show TDNase production

e and f - do not show TDNase production

g - negative control

Table 14. Incidence of TDNase in market samples of kulfi

Market	Incidence of TDNase					Staphylococcal counts/g in TDNase positive samples	
	Retail outlet code	No. of samples positive	Per cent	Zone diameter (mm)[a] Range	Average	Range	Average
Karnal	3	3	(6/30)[b]20	11.0-15.5	13.2	$39x10^5$-$52x10^6$	$22.86x10^6$
	6	3		12.5-17.0	14.8	$27x10^2$-$54x10^3$	$20.80x10^3$
Delhi	9	3	(3/30)[b]10	14.0-19.5	16.8	$58x10^5$-$96x10^5$	$74.33x10^5$

[a] This includes the diameter of well (7 mm)

[b] Numerator in the parenthesis indicates total number of TDNase positive sample and denominator indicates the number of samples tested for a particular market.

Table 15. Rapid detection of coliforms in market samples of kulfi

Coliforms per g (range)	No. of samples	Time of gas production (hr)
1-10	Nil	Nil
11-100	3	8.5 - 9.0
101-1000	36	6.5 - 7.5
1001-10000	18	5.0 - 5.7
> 10000	3	2.5 - 2.7
Total	60	

can survive subsequent heat treatment and carried over to milk products like kulfi (Batish and Chander, 1987). The present findings are significant in relation to the public health hazards caused by staphylococcal food poisoning.

5.1.4.3 Coliform

Considerable variations were observed in coliform counts of Karnal (Table 11) and Delhi (Table 12) samples of kulfi. The mean coliform counts in kulfi samples of two markets were significantly different (Table 13) indicating that market practices influence the extent of coliform contamination. High incidence of coliform bacteria in market samples is a positive indicator of faecal contamination from utensils, equipment, personnel, water and soil (Palanniswami et al., 1988), and moulds/cones (Yadav, 1990). Out of 60 samples of kulfi, only 3 samples (Table 15) were found to contain less than 100 coliform per g, which is the maximum prescribed tolerance limit for coliform (IS: 10501-1983). High coliform counts ranging between 4 and 51 x 10^5 (average 29 x 10^3 per g) have been reported by Rao (1978). Yerriswamy et al. (1983) found rather low coliform counts ranging from 60 to 1980 per g in market samples of kulfi. This would indicate that great scope exists for preparing kulfi hygienically containing lesser number of organisms. The lower coliform counts obtained during the present investigation would point out that traders have improved the hygienic quality of kulfi now as compared with earlier findings. Much remains to be achieved to improve the hygienic standard.

All the 60 kulfi samples were subjected to rapid coliform test (Table 15). With increased coliform contamination, there was a reduction in time for the production of gas in the test samples. This method can be successfully used for routine on-line checking of coliforms in kulfi mix as well as the final product in a very short duration. Any sample which shows gas production in less than 8 hr can be treated as doubtful and remedial action taken expeditiously.

5.1.4.4 Yeast and Mould

Kulfi samples were not free from yeasts and moulds (Tables 11 and 12). Insanitary handling methods and exposure of mix to environment would lead to such contamination. The average yeast and mould counts were 6.14×10^2 and 2.11×10^2 per g for Karnal and Delhi samples of kulfi respectively (Table 13). The markets significantly ($P < 0.05$) influenced the counts. Incidence of higher yeast and mould counts in kulfi was reported by Rao (1978) where the counts varied between 50 and 13×10^4 with an average of 15×10^3 per g. In the present investigation, the contamination might have occurred from processing equipments (Yadav, 1990), earthen ware (Singh, 1978) and plastic cones (Natarajan and Nambudripad, 1980).

5.1.5 CHARACTERIZATION OF SENSORY ATTRIBUTES OF MARKET SAMPLES OF KULFI

The panelists score for flavour (50), body and texture (35), colour and appearance (10) and melting quality (5) are presented in Tables 16.1 and 16.2 for kulfi samples of Karnal and Delhi markets respectively.

5.1.5.1 Flavour

The flavour scores of kulfi samples collected from Delhi were lower than those for Karnal samples despite higher total solids and fat content. Flavour of product receives much higher weightage in overall assessment of quality than the total solids content. Higher total solids and fat in Delhi samples were responsible for heavy body and slow release of flavouring molecules. On the contrary, low total solids in some of the Karnal samples contributed to insufficient cooked flavour. Good samples of kulfi were largely characterized by slightly cooked or caramelized flavour and pleasant creamy taste. Release of flavour in the mouth should be moderately high and lingering.

Table 16.1 Sensory evaluation of market samples of kulfi collected from Karnal

Retail outlet code	Flavour	Body and texture	Colour and appearance	Melting quality
1	34.31-34.78[c] (34.55±0.19)	24.78-25.37[b] (25.11±0.24)	5.43-5.54[d] (5.48±0.04)	1.98-2.21[e] (2.10±0.09)
2	37.27-37.65[c] (37.48±0.16)	25.13-25.45[b] (25.30±0.13)	5.45-5.68[d] (5.57±0.09)	2.87-3.18[e] (3.01±0.13)
3	42.51-43.12 (42.83±0.25)	30.86-31.27[a] (31.06±0.17)	6.85-7.08 (6.96±0.09)	3.15-3.47 (3.31±0.13)
4	45.62-46.31 (45.95±0.28)	32.37-33.42 (32.92±0.43)	7.25-8.15 (7.72±0.37)	3.78-4.21 (3.98±0.17)
5	46.25-46.81 (46.59±0.28)	32.85-33.57 (32.23±0.43)	8.12-8.53 (8.34±0.17)	4.10-4.43 (4.25±0.13)
6	44.12-44.78 (44.48±0.27)	31.51-31.65 (31.58±0.06)	6.81-7.12 (6.97±0.13)	3.75-4.13 (3.91±0.15)
7	42.12-42.37 (42.24±0.10)	30.15-30.45[a] (30.31±0.12)	6.37-6.61 (6.51±0.10)	3.12-3.27 (3.19±0.06)
8	44.56-45.21 (44.91±0.26)	31.87-32.15 (31.98±0.11)	6.78-7.21 (6.98±0.17)	3.85-4.10 (3.98±0.10)
9	44.21-44.64 (44.46±0.18)	31.62-31.78 (31.70±0.07)	6.71-7.28 (6.96±0.23)	3.91-4.22 (4.07±0.13)
10	40.17-40.50 (40.33±0.14)	28.71-29.13[a] (28.92±0.17)	5.75-6.31[d] (6.02±0.23)	3.25-3.43 (3.35±0.07)

Figures in the parentheses represent the mean of three replicates with S.D.

Criticisms:
[a] Lack of fine grainy texture
[b] Icy texture
[c] Lack of cooked/caramelized flavour
[d] Whitish colour
[e] Slow melting

Table 16.2 Sensory evaluation of market samples of kulfi collected from Delhi

Retail outlet code	Flavour	Body and texture	Colour and appearance	Melting quality
1	35.17-35.59[c] (35.41±0.18)	23.42-23.65[a] (23.53±0.09)	6.71-6.89[d] (6.79±0.07)	1.23-1.57[e] (1.41±0.04)
2	34.12-34.37[c] (34.26±0.10)	24.61-24.87[a] (24.75±0.11)	6.57-6.65[d] (6.62±0.03)	1.89-2.17[e] (2.02±0.11)
3	35.57-36.18[c] (35.88±0.25)	25.15-25.69[b] (25.40±0.22)	6.78-7.13[d] (6.94±0.14)	2.13-2.47[f] (2.31±0.14)
4	34.91-35.26[c] (35.08±0.14)	24.72-25.11[b] (24.94±0.16)	6.47-6.81[d] (6.63±0.14)	1.78-2.10[f] (1.94±0.13)
5	35.18-35.36[c] (35.26±0.07)	24.13-24.47[b] (24.32±0.14)	6.52-6.77[d] (6.66±0.10)	1.87-2.05[e] (1.96±0.07)
6	34.62-34.78[c] (34.70±0.06)	23.87-24.18[a] (24.01±0.13)	6.43-6.67[d] (6.56±0.10)	1.71-1.93[e] (1.83±0.09)
7	44.19-44.52 (44.36±0.13)	31.87-32.19 (32.04±0.13)	6.91-7.23 (7.09±0.13)	3.87-4.31 (4.13±0.19)
8	45.35-45.54 (45.44±0.08)	33.52-33.87 (33.68±0.14)	7.38-7.69 (7.52±0.13)	4.15-4.31 (4.23±0.06)
9	46.58-46.81 (46.67±0.10)	33.61-34.12 (33.86±0.20)	7.35-7.62 (7.48±0.11)	4.12-4.35 (4.24±0.09)
10	45.52-45.76 (45.62±0.10)	33.78-34.03 (33.90±0.10)	7.28-7.57 (7.43±0.12)	3.65-3.78 (3.71±0.05)

Figures in the parentheses represent the mean of three replicates with S.D.

Criticisms:
[a] Soggy body
[b] Big sized coagulated milk particle
[c] Slow flavour release
[d] Brownish colour
[e] Slow melting
[f] Curdy melt down

5.1.5.2 Body and Texture

The body and texture of kulfi samples varied to a great extent. Those samples having fine grainy texture (without big coagulated milk particles) or small ice crystals were rated as best. Samples with higher total solids (46.0 to 48.0 per cent) were commented upon as soggy and heavy body. About 30 per cent of samples collected from Delhi (Table 16.2) suffered this kind of valid criticism while the same proportion received lower rating for the presence of big sized coagulated milk particles. In case of Karnal samples, about 30 per cent samples were found to be devoid of fine grainy texture and 20 per cent scored low rating due to icy texture caused by low total solids content.

5.1.5.3 Colour and Appearance

In general, the colour of kulfi samples was creamy white with slight browning. Good samples had a glossy appearance. Any deviation from these attributes was considered as a defect in the product. About 30 per cent of the samples from Karnal market showed dull whitish colour, an indication of improper heat treatment whereas about 60 per cent of Delhi samples were rated as low due to their brownish colour.

5.1.5.4 Melting Quality

The samples of kulfi showing relatively high resistance to melting during eating were judged as best. Any sample showing faster melting due to low total solids was rated inferior. Such samples which melted into a curdy fluid due to heat denaturation of proteins were not liked by the judges. An uniformly smooth melt was always preferred.

On the basis of the sensory evaluation and specific comments of the judges, it could be concluded that good quality kulfi should have the following desirable attributes.

Flavour	-	Pleasant, slight cooked/caramelized, creamy taste and free from abnormal odours.
Body and texture	-	Fine grainy texture, free from big coagulated milk particles or ice crystals.
Colour and appearance	-	Creamy white with slight brown colouration.
Melting quality	-	No perceptible melting for 7-10 min.

5.1.6 MARKET PRICES OF KULFI

Kulfi is usually sold on an individual cone basis and sometime on weight basis from a large vessel. In all 20 representative cones, 10 each from Karnal and Delhi markets were selected and weighed. The net weight of kulfi in the cones varied from 95.0 to 103.0 (average 97.2 g) and 90.0 to 107.0 g (average 96.5 g) per cone for Karnal and Delhi markets respectively. The price per kg of kulfi was worked out from retail price per cone on net weight basis (Table 17). The retail price per cone of kulfi during the years 1989-90 varied from Rs.4.50 to 6.00 and Rs.6.00 to 7.00 for Karnal and Delhi markets respectively. The average retail price of kulfi in Delhi market was found to be 16.0 per cent higher than in Karnal. The price of milk in Delhi is always higher than in Karnal. Moreover, higher milk solids contents in Delhi samples could be another reason for higher price. In Karnal market, substandard kulfi in respect of fat is sold at higher prices ranging from Rs.47.36 to 65.22 per kg. The processing, packaging and other overhead costs may be considered as nearly the same in both the markets. Depending upon the demand generated at a given time, the traders would usually change the price of kulfi and charge the opportunity cost from the consumers. Exploitive as they are, such market forces cannot be competed with unless the organized dairy sector takes to the production and marketing of kulfi. Ice cream sells at Rs.6.00 to 7.00 per 100 ml which contains about 50.0 to 55.0 g solids. This would indicate that consumers get more milk solids in kulfi for almost half the price they have to pay for the nutrients in ice cream.

Table 17. Retail prices of kulfi in Karnal and Delhi markets

Retail outlet code	Net weight/ cone (g)	Price/cone (Rs.)	Price/kg kulfi (Rs.)
		Karnal market	
1	95.0	4.50	47.36
2	98.0	5.00	51.02
3	97.0	5.00	51.55
4	95.0	5.50	57.89
5	102.0	6.00	58.82
6	92.0	6.00	65.22
7	95.0	6.00	63.16
8	97.0	6.00	61.85
9	98.0	6.00	61.22
10	103.0	6.00	58.25
Mean and SD	97.2 ± 3.15	5.60 ± 0.54	57.63 ± 5.54
		Delhi market	
1	90.0	6.50	72.22
2	94.0	6.00	63.83
3	105.0	7.00	66.66
4	98.0	6.50	66.32
5	107.0	7.00	65.42
6	92.0	6.50	70.65
7	102.0	6.00	58.82
8	95.0	6.50	68.42
9	92.0	6.50	70.65
10	90.0	6.50	72.22
Mean and SD	96.5 ± 5.90	6.50 ± 0.32	67.52 ± 4.00

5.2 FORMULATION OF KULFI MIX AND OPTIMIZATION OF PROCESSING PARAMETERS FOR MANUFACTURE OF KULFI

The survey of kulfi trade revealed that there are wide variations in the manufacturing practices, chemical composition and sensory properties of the traditional product. The microbiological quality of kulfi was also found to be far from satisfactory. There is hardly any standard method for kulfi making used by the traders. The need for standardizing the technology for commercial kulfi production became imperative. These studies included the optimization of product mix in respect of fat, MSNF, sugar and stabilizer, and process standardization involving homogenization pressures, different heat treatments and methods of freezing.

5.2.1 OPTIMUM FAT IN KULFI

The effects of different fat percentages, viz., 7.0, 9.0, 11.0 and 13.0 on mix composition, physico-chemical characteristics and sensory properties of kulfi are discussed in the following sections.

5.2.1.1 Composition

There was a slight increase in MSNF content (Table 18) of kulfi mix containing more than 9.0 per cent fat. This could be attributed to the serum solids associated with cream used as a source of fat. Sugar level was kept constant at 13.0 per cent for all the combinations. As expected, TS in kulfi mix also increased from 34.03 to 40.29 per cent depending on the amount of cream added.

5.2.1.2 Physico-chemical Characteristics

The physico-chemical characteristics of kulfi mix and melt down of kulfi as influenced by various levels of fat have been presented in Table 18.

Table 18. Composition and physico-chemical characteristics of kulfi mix prepared with different levels of fat

Characteristics	Levels of fat (per cent)				
	Control (8.0)	7.0	9.0	11.0	13.0
Fat (per cent)	7.95-8.13 (8.10±0.06)	6.98-7.10 (7.05±0.05)	8.92-9.13 (9.04±0.08)	10.88-11.12 (11.03±0.10)	12.92-13.15 (13.05±0.09)
MSNF (per cent)	13.97-14.01 (13.99±0.02)	13.93-14.03 (13.98±0.04)	13.97-14.03 (14.00±0.02)	14.06-14.17 (14.12±0.05)	14.22-14.29 (14.25±0.03)
Sugar (per cent)	13.0	13.0	13.0	13.0	13.0
Total solids (per cent)	34.92-35.14 (35.09±0.11)	33.91-34.12 (34.03±0.09)	35.95-36.10 (36.02±0.06)	37.94-38.29 (38.19±0.07)	40.21-40.37 (40.29±0.06)
Acidity (% LA)	0.22-0.23 (0.23±0.004)	0.22-0.23 (0.23±0.004)	0.22-0.23 (0.23±0.004)	0.23-0.24 (0.24±0.004)	0.23-0.24 (0.24±0.004)
pH	6.50-6.48 (6.49±0.008)	6.50-6.48 (6.49±0.008)	6.50-6.49 (6.50±0.004)	6.48-6.46 (6.47±0.008)	6.48-6.46 (6.47±0.008)
Specific gravity	1.1026-1.1029 (1.1028±0.004)	1.1032-1.1035 (1.1034±0.004)	1.1012-1.1017 (1.1015±0.004)	1.0993-1.0999 (1.0997±0.0004)	1.0970-1.0981 (1.0975±0.0004)
Relative viscosity	1.58-1.59 (1.59±0.004)	1.56-1.59 (1.58±0.01)	1.61-1.65 (1.63±0.02)	1.63-1.69 (1.66±0.02)	1.73-1.78 (1.75±0.02)
Surface tension (dynes/cm)	49.3-49.7 (49.58±0.19)	49.7-50.1 (49.90±0.16)	48.8-49.2 (49.00±0.17)	48.1-48.4 (48.27±0.12)	47.4-47.9 (47.70±0.21)
Kulfi melt down (ml/30 min)	27.0-27.3 (27.17±0.12)	27.5-28.0 (27.77±0.20)	26.7-27.1 (26.87±0.17)	25.4-25.7 (25.57±0.12)	24.6-25.2 (24.90±0.24)

Figures in parentheses represent means of three replicates with SD

Heat treatment - 85°C/30 sec; Freezing - Traditional method

The mean acidity for kulfi mix expressed as per cent lactic acid was found to increase slightly with increased fat beyond 11.0 per cent with corresponding decrease in pH. Increased MSNF in cream which served as a fat source in the mix contributed to increased acidity.

The mean specific gravity of kulfi mix was found to decrease with increasing fat percentage. Fat being lighter than serum solids would depress the specific gravity. The variations in specific gravity due to fat levels could also be attributed to variations in the ratio of solid to liquid fat (Webb et al., 1974) which could change due to factors like heating and freezing of mix.

Relative viscosity of kulfi mix was found to increase with increasing levels of fat. The rate of increase in relative viscosity was more when fat level was increased from 11.0 to 13.0. High fat content increases the number of fat globules which in turn contributes to viscosity consequent to clustering of fat globules. Abu-Lehia et al. (1989) also observed increased viscosity in ice-cream mix when fat level was raised from 4.0 to 12.0 per cent.

Surface tension of mix decreased with increase in fat content. Protein and protein-phospholipid complex at the surface of milk fat globules acts as a powerful surface tension depressant at plasma/fat interface. With the increased fat content, the concentration of such surface active agents increases causing a decrease in surface tension values (Sommer, 1951).

The mean melt down of kulfi was found to decrease with the increase in fat content. This may be attributed to increase in viscosity of mix caused by gradual increase in fat and MSNF. Above 11.0 per cent fat, the

product acquired a creamy paste like body having comparatively high melting resistance due to insulating effect of fat (Arbuckle, 1986).

5.2.1.3 Sensory Properties

The sensory scores of kulfi with different levels of fat have been presented in Table 19 and statistical inference of data shown in Table 20.

The mean flavour score of kulfi increased with increased fat content. The highest sensory scores were received by kulfi samples prepared with 11.0 per cent fat. However, the flavour scores decreased with further increase in fat content although these scores were higher than the control samples (8.0 per cent fat). Changes in the scores were found to be significant at $P < 0.01$. Kulfi samples with 11.0 per cent fat were creamier in taste and smoother in texture. Further increase in fat produced a buttery taste in the product which was not liked by the judges.

The body and texture scores of kulfi also increased significantly ($P < 0.01$) with the increase in fat upto 11.0 per cent. Higher percentages of fat in kulfi mix were responsible for lower texture score. Interestingly, the lowest scores were awarded to product made from 7.0 per cent fat which was criticized for crumbly body and icy texture. Such a low fat content can lead to body defects (Arbuckle, 1986). Another observation made was that soggy body and butterytexture is produced when the mix contains 13.0 per cent fat.

The intensity of creamy white colour and smooth glossy appearance increased with the increasing levels of fat in kulfi. The product with 11.0 per cent fat received the highest rating (Table 19). With further increase in fat, the product tends to stick to the moulds and the appearance becomes uneven leading to lower appearance scores. The changes in appearance scores were found to be significant at $P < 0.01$.

Table 19. Mean sensory scores of kulfi prepared with different levels of fat

Levels of fat (per cent)	Sensory attributes			
	Flavour	Body and texture	Colour and appearance	Melting quality
Control	39.13	32.36	8.53	4.21
7.0	38.49	30.68	8.12	3.82
9.0	41.40	33.40	8.67	4.39
11.0	44.96	34.74	9.24	4.52
13.0	42.51	33.81	8.97	4.17

Table 20. ANOVA for sensory evaluation scores of kulfi prepared with different levels of fat

Sources of variation	d.f.	Mean sum of squares			
		Flavour	Body and texture	Colour and appearance	Melting quality
Replicates	2	0.0011	0.0035	0.0018	0.0018
Treatments	4	20.6012**	7.2563**	0.5512**	0.2102**
Error	8	0.0136	0.0016	0.0030	0.0005

** Significant at $P < 0.01$

Melt down resistance improved with increasing fat content upto 11.0 per cent. An abnormal increase in melt down resistance (13.0 per cent fat) adversely affected the sensory scores.

On the basis of physico-chemical characteristics and sensory attributes, it could be concluded that kulfi made from mix containing 11.0 per cent fat is most acceptable. Hence, selected for further investigation.

5.2.2 OPTIMUM AMOUNT OF MSNF IN KULFI

The influence of various MSNF contents, viz., 14.0, 15.0, 16.0 and 17.0 per cent on product quality have been presented under three sections, i.e., composition, physico-chemical characteristics and sensory attributes. In all the samples, fat was standardized to 11.0 per cent and sucrose kept constant at 13.0 per cent.

5.2.2.1 Composition

The average TS in kulfi mix increased from 38.11 to 41.10 per cent with the increased addition of MSNF (Table 21). The mean fat content in the control sample of kulfi mix was 8.10 per cent and TS 35 per cent. All the experimental samples contained about 11.0 per cent fat.

5.2.2.2 Physico-chemical Characteristics

The physico-chemical characteristics of kulfi mix and melt down of kulfi as influenced by various levels of MSNF have been presented in Table 21.

The acidity value (per cent LA) for kulfi mix was found to increase linearly with the increase in MSNF content from 14.0 to 17.0 per cent while the pH got reduced. Similar observations were reported for kulfi mix by Salooja (1979). Acidity of ice cream mix is influenced by MSNF contents

Table 21. Composition and physico-chemical characteristics of kulfi mix prepared with different levels of MSNF

Characteristics	Levels of MSNF (per cent)				
	Control (14.0)	14.0	15.0	16.0	17.0
Fat (per cent)	7.90-8.12 (8.10±0.07)	10.92-11.15 (11.08±0.06)	10.85-11.07 (11.02±0.07)	10.91-11.10 (11.08±0.04)	10.87-11.06 (10.96±0.07)
Sugar (per cent)	13.0	13.0	13.0	13.0	13.0
Total solids (per cent)	34.89-35.10 (35.02±0.12)	37.87-38.14 (38.11±0.04)	38.95-39.10 (39.08-0.05)	39.99-40.13 (40.07±0.03)	41.10-41.13 (41.10±0.08)
Acidity (% LA)	0.22-0.23 (0.23±0.004)	0.23-0.24 (0.24±0.004)	0.24-0.25 (0.25±0.004)	0.25-0.26 (0.26±0.004)	0.26-0.27 (0.27±0.004)
pH	6.50-6.48 (6.49±0.008)	6.49-6.46 (6.47±0.008)	6.46-6.43 (6.44±0.008)	6.42-6.39 (6.41±0.009)	6.40-6.37 (6.39±0.008)
Specific gravity	1.1026-1.1031 (1.1029±0.0004)	1.0989-1.0997 (1.0995±0.0004)	1.1039-1.1043 (1.1041±0.0004)	1.1084-1.1088 (1.1086±0.0004)	1.1129-1.1134 (1.1132±0.0004)
Relative viscosity	1.56-1.59 (1.57±0.07)	1.64-1.67 (1.66±0.04)	1.68-1.72 (1.71±0.17)	1.71-1.76 (1.75±0.18)	1.75-1.81 (1.79±0.12)
Surface tension (dynes/cm)	49.5-49.8 (49.72±0.08)	48.1-48.6 (48.43±0.15)	47.6-48.2 (47.93±0.21)	47.1-47.4 (47.23±0.20)	46.8-47.2 (46.93±0.39)
Kulfi melt down (ml/30 min)	26.8-27.2 (26.93±0.12)	25.1-25.5 (25.41±0.17)	26.0-26.4 (26.21±0.20)	26.8-27.3 (27.12±0.24)	27.4-27.9 (27.73±0.19)

Figures in parentheses represent means of three replicates with SD

Heat treatment - 85°C/30 sec; Freezing - Traditional method

(Arbuckle, 1986). In the present study, the changes in acidity values and pH in kulfi were mainly due to changes in MSNF content. The heat treatment of the mixes was kept identical in the experiment. The heat induced changes in acidity and pH of processed kulfi mixes could be similar. The effects of heating on acidity and pH of mix were investigated separately (section 5.2.7.1).

The mean specific gravity of kulfi mix was found to increase with the increase in MSNF content from 14.0 to 17.0 per cent. Salam et al. (1981) reported that the specific gravity of ice cream mix increased from 1.079 to 1.095 when MSNF level in the mix was increased from 6.0 to 12.0 per cent.

There was a gradual build up of relative viscosity in kulfi mix with increased MSNF from 14.0 to 17.0 per cent. It is generally agreed that milk proteins, particularly casein, significantly contribute towards viscosity than other milk constituents. Substantial increases in viscosity due to increased MSNF in kulfi and ice-cream were respectively reported by Salooja (1979) and Salam et al. (1981).

The surface tension of kulfi mix decreased with increase in MSNF content from 14.0 to 17.0 per cent. The decrease in surface tension may be attributed to the increase in the concentration of surface active substances viz., casein, β-lactoglobulin and α-lactalbumin at the surface film (Igarashi and Saito, 1972). Similar observations were made in respect of surface tension by Salooja (1979) in the preparation of kulfi.

The melt down increased with increasing MSNF content. Higher amounts of lactose and soluble minerals would cause a significant depression in the freezing point of the mix. Because of freezing point depression, the amount of water frozen in kulfi at the freezing temperature decreased and the

amount of water remaining unfrozen was more, which increased the rate of melting (Salooja, 1979).

5.2.2.3 Sensory Properties

The flavour scores with different levels of MSNF were found to differ significantly. Flavour scores increased with increasing MSNF content upto 16.0 per cent and further increase caused reduction in the scores (Table 22). This could be explained on the basis that low MSNF per cent gives incomplete flavour perception in the mouth. However, with gradual increase in MSNF content, the flavour scores improved. At 17 per cent MSNF, the panelists adversely commented on the flavour. Heavy body kulfi as a result of high MSNF content takes time to melt and the release of flavour volatiles in the mouth gets delayed.

The body and texture scores of kulfi increased significantly with the increase in MSNF content (Table 23). Kulfi samples with 16.0 per cent MSNF were rated as the best. The textural preference in descending order was for the samples prepared with 17.0, 15.0 and 14.0 per cent MSNF (Table 22). The body of kulfi was crumbly in samples prepared with 14 per cent MSNF. This defect got eliminated with increasing level of MSNF upto 16.0 per cent. Beyond this level, the product became soggy and not liked by the judges.

Kulfi samples prepared with different MSNF levels had creamy white to brownish colour. The browning increased with increasing level of MSNF in the mix. Heating of mix with high milk solids is expected to cause browning to proceed faster than low solids kulfi mix. The appearance of kulfi also got improved significantly with increasing MSNF content. It appears that emulsifying property associated with MSNF content might have improved the smooth and glossy appearance of kulfi when drawn out from moulds.

Table 22. Mean sensory scores of kulfi prepared with different levels of MSNF

Levels of MSNF (per cent)	Sensory attributes			
	Flavour	Body and texture	Colour and appearance	Melting quality
Control	40.33	32.27	8.53	4.29
14.0	41.21	32.86	9.22	4.37
15.0	43.85	33.69	9.36	4.51
16.0	45.80	34.50	9.44	4.62
17.0	44.40	33.90	9.65	4.48

Table 23. ANOVA for sensory evaluation scores of kulfi prepared with different levels of MSNF

Sources of variation	d.f.	Mean sum of squares			
		Flavour	Body and texture	Colour and appearance	Melting quality
Replicates	2	0.0008	0.0011	0.0004	0.0068
Treatments	4	15.5657**	2.3307**	0.5503**	1.7769**
Error	8	0.0002	0.0016	0.0008	0.0038

** Significant at $P < 0.01$

The changes in melting quality of kulfi were found to be significant. MSNF content had a definite influence on melting quality. The products with 16.0 per cent MSNF were rated as the best (Table 22). MSNF content lower or higher than 16 per cent produced slow and fast melting kulfi, respectively.

On the basis of physico-chemical characteristics of kulfi mix as influenced by the different levels of MSNF and the effects on sensory attributes of kulfi, it could be concluded that the product made from mix containing 16.0 per cent MSNF was most acceptable. Hence, selected for further investigations.

5.2.3 OPTIMUM SUGAR CONTENT IN KULFI

The sugar content affects the freezing behaviour and physico-chemical and sensory properties of frozen dairy products. The influences of three sugar levels, viz., 14.0, 15.0 and 16.0 per cent on kulfi mix and frozen product quality were studied in respect of composition, physico-chemical characteristics (Table 24) and sensory properties.

5.2.3.1 Composition

The mean total solids content of experimental kulfi mix increased from 41.11 to 43.04 per cent due to incremental addition of sugar (Table 24). The fat content of control samples was adjusted to 8.04 per cent and those of the experimental samples around 11.0 per cent.

5.2.3.2 Physico-chemical Characteristics

No appreciable changes were noted in mean acidity values of kulfi mix samples with 14.0 and 15.0 per cent sugar. pH values also remained fairly constant inspite of the changes in sugar content. A minor increase in acidity took place at 16.0 per cent sugar level. Sugar is known to show some

Table 24. Composition and physico-chemical characteristics of kulfi mix prepared with different levels of sugar

Characteristics	Levels of sugar (per cent)			
	Control (13.0)	14.0	15.0	16.0
Fat (per cent)	7.87-8.10 (8.04±0.10)	10.93-11.10 (11.06±0.05)	10.90-11.07 (10.98±0.05)	10.87-11.05 (10.97±0.07)
MSNF (per cent)	14.0	16.0	16.0	16.0
Total solids (per cent)	34.88-35.13 (35.04±0.11)	40.95-41.17 (41.11±0.09)	41.88-42.12 (41.97±0.07)	42.93-43.15 (43.04±0.09)
Acidity (% LA)	0.22-0.23 (0.23±0.004)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)	0.26-0.27 (0.27±0.004)
pH	6.50-6.48 (6.49±0.008)	6.42-6.40 (6.41±0.009)	6.42-6.39 (6.40±0.008)	6.38-6.36 (6.37±0.009)
Specific gravity	1.1028-1.1032 (1.1030±0.0004)	1.1128-1.1136 (1.1134±0.0004)	1.1176-1.1180 (1.1178±0.0004)	1.1221-1.1227 (1.1225±0.0004)
Relative viscosity	1.59-1.61 (1.60±0.08)	1.73-1.78 (1.75±0.04)	1.71-1.75 (1.73±0.02)	1.68-1.72 (1.70±0.01)
Surface tension (dynes/cm)	49.3-49.9 (49.60±0.24)	47.1-47.3 (47.10±0.17)	47.1-47.3 (47.16±0.12)	46.9-47.2 (47.10±0.12)
Kulfi melt down (ml/30 min)	27.2-27.5 (27.36±0.12)	26.1-26.7 (26.43±0.12)	27.8-28.3 (28.07±0.20)	29.0-29.5 (29.27±0.20)

Figures in parentheses represent means of three replicates with SD

Heat treatment - 85°C/30 sec; Freezing - Traditional method

Table 25. Mean sensory scores of kulfi prepared with different levels of sugar

Levels of sugar (per cent)	Sensory attributes			
	Flavour	Body and texture	Colour and appearance	Melting quality
Control	41.20	32.59	8.48	4.25
14.0	43.90	33.82	8.74	4.43
15.0	45.80	34.77	8.92	4.53
16.0	45.10	34.56	8.75	4.36

Table 26. ANOVA for sensory evaluation scores of kulfi prepared with different levels of sugar

Sources of variation	d.f.	Mean sum of squares			
		Flavour	Body and texture	Colour and appearance	Melting quality
Replicates	2	0.0003	0.0023	0.0007	0.00008
Treatments	3	12.2627**	2.9149**	0.2689**	1.4542**
Error	6	0.0003	0.0005	0.0006	0.0015

** Significant at $P < 0.01$

natural acidity for variety of reasons. At lower level of sugar, viz., 14.0 and 15.0 per cent, the buffering capacity of proteins and salts was sufficient to resist any change in acidity and pH of the system.

The mean specific gravity of kulfi mix increased with the increase in sugar percentages. Specific gravity of kulfi mix is expected to increase with increase in total solids, especially the MSNF.

There was a gradual decrease in relative viscosity with increased sugar content. Sugars are strong water binding agents. Sugars retard hydration of proteins by competitive binding of water molecules and interfering with the formation of junction zones (Whistler and Daniel, 1985).

The surface tension values were not affected by the addition of sugar. This would indicate that sugar did not contribute to the surface active properties of kulfi mix.

The melt down of kulfi increased with the increasing sugar content. Gradual depression of freezing point with increase in sugar content increased the amount of unfrozen water in the mould and as a result decreased the melting resistance of the product.

5.2.3.3 Sensory Properties

The changes in flavour scores with different levels of sugar were found significant at $P < 0.01$ (Table 26). The main function of the sugar is to increase the acceptance of the product, not only by making it sweeter but more especially by enhancing the pleasing creamy taste and delicate flavour (Arbuckle,1986). The lower scores for the control and the samples containing 14.0 per cent sugar were mainly due to lack of adequate sweetening (Table 25). On the other hand, sugar levels above 15.0 per cent, caused excessive sweetness and overshadowed the delicate flavour of kulfi. The

samples of kulfi prepared with 15.0 per cent sugar were rated as the best by the panelists from flavour standpoint.

The changes in body and texture scores with different levels of sugar were found to be significant at $P < 0.01$ (Table 26). The lower sensory scores for control and samples containing 14.0 per cent sugar could largely be attributed to weak body caused by low total solids. Body and texture of kulfi improved with 15.0 per cent sugar (Table 25). Above this level, the product became slightly soggy due to high TS content (43.0 per cent). Arbuckle (1986) observed that sugar improves the body and texture of ice-cream provided TS content does not exceed 42.0 per cent. Above this limit, ice cream tends to become soggy and sticky. The sugar, being in solution, depresses the freezing point of kulfi mix. This results in slower freezing and requires a lower temperature for proper hardening. It is for these reasons that an optimum level of 15.0 per cent sugar is recommended for kulfi making.

The smooth, glossy and dry appearance of the product changed significantly ($P < 0.01$) with different levels of sugar. Gradual increase in sugar level improved the scores upto 15.0 per cent. Beyond this level, the appearance of the product was moist due to incomplete freezing of mix.

The variations in sugar level significantly affected the melting quality of kulfi. Control and experimental samples containing 14.0 per cent sugar had lower scores compared with the samples containing 15.0 per cent sugar due to slow melting characteristic. Product with 16.0 per cent sugar showed low melting resistance, hence received low rating.

On the basis of physico-chemical characteristics of kulfi mix and and its effect on sensory qualities of kulfi, it could be concluded

that the product made from mix containing 15.0 per cent sugar was most liked by the judges.

5.2.4 OPTIMUM AMOUNT OF SODIUM ALGINATE IN KULFI

The primary purpose of incorporating stabilizer to kulfi mix was to improve the body, texture and melting resistance of the frozen product. The influences of various levels of sodium alginate, viz., 0.10, 0.20, 0.30 and 0.40 per cent on the composition, physico-chemical characteristics and sensory properties of kulfi are presented hereunder.

5.2.4.1 Composition

The sugar, fat and MSNF contents were kept constant at 15.0, 11.0 and 16.0 per cent, respectively in the trials on sodium alginate. The mean TS content of experimental kulfi mix increased from 42.08 to 42.41 per cent (Table 27) due to increased amount of alginate from 0.10 to 0.40 per cent.

5.2.4.2 Physico-chemical Characteristics

The mean acidity values remained unchanged in the control and experimental samples containing 0.10 and 0.20 per cent sodium alginate (Table 27). Further increase in the quantity of sodium alginate caused gradual decrease in acidity of the mix. The pH remained unaltered upto 0.20 per cent addition of sodium alginate beyond which it increased slightly with increased proportion of stabilizer. Similar observation was made by Ashokraju et al. (1989) in kulfi mix containing sodium alginate. A comparatively lower dissociation of lactic acid molecules in a highly viscous system is expected to raise pH value in any food system.

The mean specific gravity of kulfi mix increased with the increased dose of sodium alginate. The rate of increase in specific gravity in case of

Table 27. Composition and physico-chemical characteristics of kulfi mix prepared with different levels of sodium alginate

Characteristics	Levels of sodium alginate (per cent)				
	Control	0.10	0.20	0.30	0.40
Fat (per cent)	10.95-11.12 (11.07±0.07)	10.95-11.08 (10.98±0.06)	10.90-11.06 (11.02±0.07)	10.97-11.10 (11.05±0.05)	10.93-11.04 (10.97±0.06)
MSNF (per cent)	16.0	16.0	16.0	16.0	16.0
Sugar (per cent)	15.0	15.0	15.0	15.0	15.0
Total solids (per cent)	41.92-42.09 (41.98±0.06)	41.90-42.11 (42.08±0.05)	42.11-42.27 (42.21±0.06)	42.25-42.39 (42.32±0.07)	42.35-42.47 (42.41±0.05)
Acidity (% LA)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)	0.24-0.25 (0.25±0.004)	0.23-0.24 (0.24±0.004)
pH	6.42-6.40 (6.41±0.008)	6.42-6.40 (6.41±0.009)	6.42-6.39 (6.40±0.008)	6.46-6.43 (6.44±0.008)	6.48-6.45 (6.46±0.009)
Specific gravity	1.1173-1.1179 (1.1175±0.0004)	1.1178-1.1184 (1.1182±0.0004)	1.1196-1.1205 (1.1201±0.0004)	1.1211-1.1217 (1.1215±0.0004)	1.1221-1.1225 (1.1223±0.0004)
Relative viscosity	1.76-1.81 (1.79±0.22)	1.82-1.88 (1.87±0.17)	2.05-2.17 (2.14±0.20)	3.10-3.21 (3.18±0.17)	4.46-4.58 (4.54±0.06)
Surface tension (dynes/cm)	47.1-47.3 (47.17±0.09)	47.4-47.8 (47.62±0.16)	48.5-49.1 (48.83±0.15)	49.3-49.7 (49.52±0.25)	49.5-50.0 (49.88±0.25)
Kulfi melt down (ml/30 min)	27.8-28.5 (28.32±0.20)	26.1-26.6 (26.42±0.12)	25.4-25.9 (25.64±0.12)	23.4-23.7 (23.53±0.17)	21.6-22.3 (21.82±0.24)

res in parentheses represent means of three replicates with SD

t treatment - 85°C/30 sec; Freezing - Traditional method

0.30 to 0.40 per cent sodium alginate was lesser than that for 0.20 to 0.30 per cent. Increased stabilizer levels cause the kulfi mix to become more viscous resulting in greater occlusion of air in the product and hence lower specific gravity.

As the amount of sodium alginate was increased, the relative viscosity of the mix also got increased significantly. Sodium alginate is known to reduce the amount of free water in the mix by binding it as water of hydration and immobilizing it within a gel structure (Arbuckle, 1986).

There was a marginal increase (5.0 per cent) in mean surface tension values of kulfi mix with the increase in sodium alginate (Table 27). Surface tension got increased by close gel structure formation in the mixes containing higher per cent of sodium alginate. Similar increases in surface tension were observed by Rajor (1980) and Das (1984) in the ice cream mixes formulated by them.

The melt down of kulfi got reduced substantially (23.0 per cent) with increasing percentage of sodium alginate. Consumers prefer kulfi with relatively slow melting property. Soggy kulfi samples obtained with 0.30 and 0.40 per cent sodium alginate were rather slow melting during consumption. This is not a desirable property in kulfi. The highest rate of melting was observed in the control samples manufactured without the stabilizer because of weak body of kulfi.

5.2.4.3 Sensory Properties

The changes in flavour scores for different treatments were observed to be significant at $P < 0.01$ (Table 29). The quantities of sodium alginate were observed to affect the flavour scores of kulfi. The frozen product with 0.30 and 0.40 per cent sodium alginate melted slowly as reported earlier

Table 28. Mean sensory scores of kulfi prepared with different levels of sodium alginate

Levels of sodium alginate (per cent)	Sensory attributes			
	Flavour	Body and texture	Colour and appearance	Melting quality
Control	40.75	31.79	7.45	3.75
0.1	44.85	32.59	8.41	4.05
0.2	46.12	33.85	8.75	4.22
0.3	42.19	31.12	9.00	3.15
0.4	39.17	28.40	9.15	2.10

Table 29. ANOVA for sensory evaluation scores of kulfi prepared with different levels of sodium alginate

Sources of variation	d.f.	Mean sum of squares			
		Flavour	Body and texture	Colour and appearance	Melting quality
Replicates	2	0.0013	0.0010	0.0001	0.0002
Treatments	4	24.6050**	12.3848**	2.1540**	2.3719**
Error	8	0.0004	0.0007	0.0003	0.0003

** Significant at $P < 0.01$

(Table 27) limiting the release of flavour components in the mouth. The control samples and those containing 0.10 per cent sodium alginate also earned lower scores than those containing 0.20 per cent stabilizer.

The presence of sodium alginate significantly affected the body and texture of kulfi (Table 29). The samples with different levels of sodium alginate followed a sigmoid relationship. Lower sensory scores of samples containing 0.30 and 0.40 per cent sodium alginate (Table 28) could be attributed to textural defects such as gumminess and soggy body. In case of kulfi containing 0.10 per cent sodium alginate, the body became weak with coarse icy texture whereas, kulfi samples with 0.30 and 0.40 per cent stabilizer became heavy and sticky. The body and texture scores were highest for product made with 0.2 per cent sodium alginate.

The changes in mean colour and appearance scores for different treatments were observed to be significant at $P < 0.01$. The glossy, creamy and white appearance improved with the increasing sodium alginate levels due to increased dryness of the product.

The melting quality of kulfi with different levels of sodium alginate exhibited a sigmoid pattern. The samples containing 0.10 per cent stabilizer were fast melting and those containing 0.30 and 0.40 per cent slow melting. Surprisingly all the samples prepared with sodium alginate melted in a slimy liquid which was not a desirable characteristic for good quality kulfi.

On the basis of above observations, it may be concluded that an optimum level of 0.2 per cent sodium alginate can be used as stabilizer for kulfi, although it produces a slimy melt down. It became, therefore, necessary to search for an alternate stabilizer in kulfi. From the literature review, isabgol husk was selected as an alternative stabilizer for further studies.

5.2.5 OPTIMUM LEVEL OF ISABGOL HUSK IN KULFI

The influence of various levels of isabgol husk, viz., 0.10, 0.20, 0.30 and 0.40 per cent on the composition and physico-chemical properties of kulfi mix and sensory properties of kulfi was investigated.

5.2.5.1 Composition

The mean TS content of experimental kulfi mix got slightly increased from 42.04 to 42.39 per cent due to the addition of isabgol husk (Table 30). The mean fat content of the samples remained more or less around 11.0 per cent. Sugar and MSNF contents were kept constant at 15.0 and 16.0 per cent respectively in all the combinations.

5.2.5.2 Physico-chemical Characteristics

The mean acidity and pH values remained unchanged in control and all the experimental samples with different levels of isabgol husk (Table 30). This indicates that isabgol husk exerts no influence on acidity and pH of kulfi mix.

The mean specific gravity of kulfi mix increased with increased amount of isabgol husk. However, the increase in specific gravity was marginal and lower as compared with sodium alginate (Table 27).

The relative viscosity of kulfi mix increased with the increase in the level of isabgol husk (Table 30). The effect was more pronounced with 0.30 and 0.40 per cent as compared with the lower levels. Isabgol husk immobilises the water phase and raises viscosity due to hydration. Isabgol can be considered as an effective ingredient for increasing the viscosity as sodium alginate. However, use of isabgol husk was reported to be associated with lower viscosity by Sommer (1951) and Upadhyay et al. (1978).

Table 30. Composition and physico-chemical characteristics of kulfi mix prepared with different levels of isabgol husk

Characteristics	Levels of isabgol husk				
	Control	0.10	0.20	0.30	0.40
Fat (per cent)	10.93-11.11 (11.05±0.06)	10.95-11.16 (11.06±0.09)	10.97-11.09 (11.04±0.07)	10.91-11.03 (10.98±0.05)	10.98-11.17 (11.07±0.20)
MSNF (per cent)	16.0	16.0	16.0	16.0	16.0
Sugar (per cent)	15.0	15.0	15.0	15.0	15.0
Total solids (per cent)	41.92-42.07 (41.98±0.07)	41.95-42.12 (42.04±0.07)	42.18-42.31 (42.24±0.04)	42.29-42.38 (42.34±0.06)	42.36-42.45 (42.39±0.05)
Acidity (% LA)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)
pH	6.41-6.40 (6.41±0.007)	6.42-6.40 (6.41±0.007)	6.42-6.40 (6.40±0.008)	6.42-6.40 (6.41±0.008)	6.42-6.40 (6.41±0.009)
Specific gravity	1.1173-1.1177 (1.1175±0.0004)	1.1176-1.1181 (1.1180±0.0004)	1.1188-1.1192 (1.1191±0.0003)	1.1191-1.1198 (1.1195±0.0004)	1.1205-1.1211 (1.1205±0.0003)
Relative viscosity	1.76-1.80 (1.78±0.02)	1.80-1.83 (1.81±0.17)	1.91-1.98 (1.96±0.07)	2.37-2.44 (2.39±0.04)	2.95-3.10 (2.99±0.07)
Surface tension (dynes/cm)	47.1-47.3 (47.50±0.07)	47.3-47.5 (47.41±0.06)	47.5-47.7 (47.60±0.06)	47.8-48.1 (47.90±0.31)	48.1-48.5 (48.21±0.18)
Kulfi melt down (ml/30 min)	27.6-28.2 (27.87±0.25)	27.4-27.7 (27.52±0.29)	26.8-27.3 (27.13±0.12)	25.7-26.4 (26.22±0.24)	24.6-25.1 (24.80±0.26)

Figures in parentheses represent means of three replicates with SD

Heat treatment - 85°C/30 sec; Freezing - Traditional method

There was a marginal increase in surface tension of kulfi mix with increasing level of isabgol husk. This might be due to closer gel structure formation in the mix as a result of hydration of isabgol husk. The rate of increase in surface tension was found to be lower in kulfi with isabgol than the product containing same amount of sodium alginate.

There was a significant effect on melt down of kulfi containing different levels of isabgol husk. With the increase in the stabilizer level, the melt down dropped substantially and the effect was more pronounced with 0.30 and 0.40 per cent as compared with lower amount of isabgol. Addition of excessive amount of stabilizer leads to certain body defects like 'soggy' resulting in slow melt down. Moorthy (1990) reported that low fat (8.0 per cent) ice cream containing 0.30 per cent isabgol husk had a melting rate (per cent) of about 72.3 to 75.0 at 30°C in 60 min. The melt down in the present study was only 26.0 ml at 30°C in 30 min with 0.30 per cent isabgol husk. Extrapolating this melt down value in 60 min under identical conditions, about 58.0 per cent melt down of original volume (90.0 ml) was obtained. This clearly indicates that kulfi showed higher melt down resistance than ice cream.

5.2.5.3 Sensory Properties

The different levels of isabgol husk were observed to affect the flavour scores of kulfi (Table 32). Kulfi with 0.30 and 0.40 per cent isabgol husk melted rather slowly limiting the total flavour perception in the mouth. On the other hand, kulfi with 0.10 per cent had complete flavour perception. The optimum melt down of kulfi was found in samples containing 0.20 per cent isabgol husk which scored maximum flavour scores (Table 31).

The levels of isabgol husk significantly affected the body and texture of kulfi (Table 32). Kulfi containing 0.20 per cent isabgol was

Table 31. Mean sensory scores of kulfi prepared with different levels of isabgol husk

Levels of isabgol husk (per cent)	Sensory attributes			
	Flavour	Body and texture	Colour and appearance	Melting quality
Control	40.76	31.73	7.56	3.70
0.1	45.72	33.49	8.51	4.25
0.2	47.09	34.53	8.87	4.54
0.3	43.11	32.38	9.19	3.51
0.4	39.51	30.10	9.28	2.54

Table 32. ANOVA for sensory evaluation scores of kulfi prepared with different levels of isabgol husk

Sources of variation	d.f.	Mean sum of squares			
		Flavour	Body and texture	Colour and appearance	Melting quality
Replicates	2	0.0003	0.0002	0.0009	0.0001
Treatments	4	30.7898**	8.6000**	2.3738**	2.8713**
Error	8	0.0003	0.0003	0.0007	0.0003

** Significant at $P < 0.01$

rated as best (Table 31). The lower texture scores of kulfi containing 0.30 and 0.40 per cent isabgol husk were attributed to heavy and hard body. Whereas samples containing 0.10 per cent isabgol developed slight weak and crumbly body, it is interesting to note that all the samples irrespective of the amount of isabgol husk had scored higher scores than their counterparts prepared with sodium alginate (Table 28). This is due to the fact that husk particles upon hydration and swelling assume large size network and contribute a fine granular texture to the product.

Increasing levels of isabgol husk had significant effect on colour and appearance of kulfi. These scores improved with increasing levels of stabilizer (Table 31). This could be attributed to compact and dry appearance of the product, which improved with increased levels of stabilizer.

The sensory scores awarded by the judges for melting quality of kulfi with different levels of isabgol husk followed a sigmoid pattern. The lower scoring of samples containing 0.10 per cent stabilizer was perhaps due to fast melting, while slow melting property caused by 0.3 and 0.4 per cent isabgol in the product mix was not liked by the judges. All the samples treated with isabgol melted in a fine grainy liquid with no stickiness whereas it was not so in samples prepared with sodium alginate.

It may be concluded that most acceptable kulfi in terms of body and texture can be produced by incorporating 0.2 per cent isabgol in the mix.

5.2.6 OPTIMUM HOMOGENIZATION PRESSURE

On the basis of ingredient optimization studies reported in the foregoing sections (5.2.1 to 5.2.5), an ideal kulfi mix was prepared with the following composition:

Ingredient	Per cent
Fat	11.0
MSNF	16.0
Sugar	15.0
Isabgol husk	0.20

The mix was homogenized at three different pressures, viz. 6.86/3.43, 10.29/3.43 and 13.72/3.43 MPa with the main objective of making a permanent and uniform emulsion of fat. In the present instance, lower homogenization pressures were used for kulfi mix than those recommended for ice cream mixes which may require a total pressure of 15.9 to 22.0 MPa, two-third of which is the first stage and the balance one-third in the second stage. The effects of homogenization on the physico-chemical characteristics of kulfi mix (Table 33) and sensory attributes of kulfi (Tables 34 and 35) are discussed here.

5.2.6.1 Physico-chemical Characteristics

The mean acidity and pH values of kulfi mix remained unaltered with the change in homogenization pressure.

Higher homogenization pressure caused increase in mean specific gravity of kulfi mix. Homogenization breaks the large sized fat globules into tiny entities, the diameter of which may not exceed 2 microns. The smaller fat particles pack well leading to reduction in overall volume of homogenized mix as compared with unhomogenized mix (Jain and Verma,1970), although total volume of fat is not altered.

Relative viscosity of kulfi mix increased with the increase in homogenization pressure. This could be attributed to lipo-protein complex of newly formed fat globule membrane, which might cause a slight increase in

Table 33. Effect of homogenizing pressures on the physico-chemical characteristics of kulfi mix

Characteristics	Homogenization pressure (MPa) - 2 stages			
	Control	6.86/3.43	10.29/3.43	13.72/3.43
Acidity (% LA)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.25±0.004)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)
pH	6.42-6.40 (6.41±0.009)	6.42-6.40 (6.41±0.008)	6.42-6.40 (6.41±0.009)	6.42-6.40 (6.41±0.009)
Specific gravity	1.1188-1.1192 (1.1190±0.0004)	1.1197-1.1205 (1.1201±0.0004)	1.1214-1221 (1.1219±0.0004)	1.1232-1.1239 (1.1235±0.0004)
Relative viscosity	1.92-1.96 (1.94±0.02)	1.99-2.11 (2.05±0.05)	2.28-2.35 (2.33±0.07)	2.41-2.43 (2.42±0.05)
Surface tension (dynes/cm)	47.5-47.7 (47.63±0.09)	47.9-48.5 (48.20±0.24)	48.9-49.2 (49.03±0.012	49.1-49.6 (49.33±0.20)
Kulfi melt down (ml/30 min)	26.8-27.3 (27.07±0.20)	26.0-26.5 (26.77±0.20)	25.2-25.7 (25.47±0.20)	24.3-24.8 (24.53±0.20)

Figures in parentheses represent means of three replicates with SD

Heat treatment - 85°C/30 sec; Freezing - Traditional method

"bound water" as compared with unhomogenized mix (Arbuckle,1986). Viscosity of ice cream mix was also reported to have increased with increasing homogenization pressures (Usacheva and Tverdokhlea, 1978).

Surface tension values of kulfi mix were found to increase progressively with the increase in homogenization pressure. Reduction in the amount of protein available to milk-air interface because of adsorption on the newly formed fat globule surfaces may cause such change (Sherbon, 1988). Another plausible reason for increased surface tension may be the reduction in free fat in the mix due to homogenization.

Kulfi samples melted slowly with increasing homogenization pressures. Improvement in the relative viscosity and consistency of kulfi mix due to increasing homogenization pressures and reduction in the amount of free water may be the possible factors for slow melting.

5.2.6.2 Sensory Properties

The mean flavour score of kulfi increased with increased homogenization pressures (Table 34) and the changes were found significant at 1 per cent level of significance (Table 35). The highest sensory scores were received by kulfi samples prepared from the mix homogenized at 13.72/3.43 followed a descending order by 10.29/3.43 and 6.86/3.43 MPa pressures. Unhomogenized control samples carried the lowest flavour scores. Increasing homogenization pressures are known to improve smoothness and creaminess (mouthfeel) of ice cream by making finer fat dispersion (White, 1981).

The body and texture scores of kulfi also changed significantly ($P < 0.01$) with the increase in homogenization pressure (Table 35). Kulfi samples prepared after homogenizing at 6.86/3.43 MPa were found to be best. Higher pressures of 10.29/3.43 and 13.72/3.43 MPa were not necessary

Table 34. Mean sensory scores of kulfi prepared by using different homogenization pressures

Homogenization pressure (MPa)	Sensory attributes			
	Flavour	Body and texture	Colour and appearance	Melting quality
Control	40.72	32.38	7.42	4.22
6.86/3.43	41.74	34.55	8.11	4.67
10.29/3.43	43.12	31.21	8.89	3.83
13.72/3.43	44.63	28.11	9.71	3.27

Table 35. ANOVA for sensory evaluation scores of kulfi prepared by using different homogenization pressures

Sources of variation	d.f.	Mean sum of squares			
		Flavour	Body and texture	Colour and appearance	Melting
Replicates	2	0.0001	0.0010	0.0003	0.0003
Treatments	3	14.1097**	22.4852**	2.9148**	1.4533**
Error	6	0.0004	0.0002	0.0004	0.0004

** Significant at $P < 0.01$

(Table 34). Unhomogenized samples had a coarse grainy texture which improved upon homogenization at 6.86/3.43 MPa. Further increase in homogenization pressure rendered the product very smooth (lack of fine grains) which is an undesirable attribute of kulfi.

The intensity of creamy white colour and glossy appearance increased with the increased homogenization pressure (Table 34) and the changes were found statistically significant at $P < 0.01$ (Table 35). Very small fat globules are formed because of increased homogenization pressure. This leads to greater scattering of light and this phenomenon improves the creamy white colour. Schmidt and Smith (1987) reported that increase in homogenization pressure makes ice cream more glossier.

Melting quality of kulfi changed significantly with the increase in homogenization pressure (Table 35). Kulfi samples prepared after homogenizing at 6.86/3.43 MPa pressures were judged as best followed in descending order by control (unhomogenized), 10.29/3.43 and 13.72/3.43 MPa pressures. Control samples of kulfi had the least melting resistance. Higher homogenizing pressures increase melting resistance, which is not liked by the judges.

It may be concluded that kulfi prepared after homogenization at 6.86/3.43 MPa is most acceptable. Although higher homogenization pressures improve the flavour quality, the body and texture scores get reduced. High homogenizing pressure will also increase the overall processing cost.

5.2.7 OPTIMUM DEGREE OF HEAT TREATMENT

Proper heating of kulfi mix is essential to mix all the ingredients uniformly, to destroy most pathogenic organisms and to impart characteristic cooked or slightly caramelized flavour. The influences of various heat treatments (100°C for 5, 10 and 15 min) on kulfi mix and the frozen product,

in respect of physico-chemical characteristics (Table 36), sensory quality (Tables 37 and 38) and heat induced changes in proteins are described hereunder.

5.2.7.1 Physico-chemical Characteristics

Prolonged treatment of kulfi mix at 100°C for 5, 10 and 15 min in a tubular heat exchanger caused an increase in the acidity values and decrease in pH values. The decrease in pH upon heating of mix can be ascribed to changes in the buffering capacity and release of carbon dioxide. Heating of milk results in the production of organic acids from heat degradation products of lactose, the release of hydrogen ions by precipitation of primary and secondary calcium phosphate and hydrolysis of casein phosphate and its subsequent precipitation as $Ca_3 (PO_4)_2$ (Fox, 1981a,b).

Specific gravity of kulfi mix was found to increase with the time of heating at 100°C. Casein micelles upon heating aggregate and form strands of protein (Fox, 1981a) having compact structure which might increase the specific gravity.

p-DMAB values also increased with increase in severity of heat treatment. Similar observations were made by Ranganadham (1988) during heat processing of concentrated milk intended for khoa powder manufacture.

Prolonged heat treatment at elevated temperatures increases the viscosity of kulfi mix (Yerriswamy et al., 1984) due to structural reorganization of casein micelles. Similar results were also obtained in the present investigation.

Surface tension values of kulfi mix increased with long heat exposure. This effect undoubtedly occurred from denaturation and coagulation of milk proteins so that these were no longer effective surface active agents (Sherbon, 1988).

Table 36. Effect of different heat treatments on the physico-chemical characteristics of kulfi mix

Characteristics	Heat treatments (°C/min)			
	Control	100/5	100/10	100/15
Acidity (% LA)	0.25-0.26 (0.26±0.004)	0.25-0.26 (0.26±0.004)	0.27-0.28 (0.28±0.004)	0.29-0.30 (0.30±0.004)
pH	6.42-6.40 (6.41±0.008)	6.41-6.38 (6.39±0.01)	6.39-6.37 (6.38±0.008)	6.36-6.33 (6.34±0.01)
Specific gravity	1.1197-1.1207 (1.1201±0.0004)	1.1205-1.1217 (1.1211±0.0004)	1.1224-1.1229 (1.1226±0.0002)	1.1238-1.1244 (1.1240±0.0002)
p-DMAB reactivity (absorbance at 545 nm)	0.042-0.048 (0.045±0.002)	0.141-0.158 (0.151±0.007)	0.197-0.211 (0.204±0.005)	0.253-0.265 (0.259±0.004)
Relative viscosity	1.99-2.15 (2.06±0.06)	2.18-2.27 (2.23±0.04)	2.38-2.41 (2.39±0.01)	2.45-2.50 (2.47±0.02)
Surface tension (dynes/cm)	47.9-48.5 (48.20±0.24)	48.5-49.1 (48.76±0.25)	48.9-49.7 (49.23±0.34)	49.9-50.3 (50.10±0.16)
Kulfi melt down (ml/30 min)	26.1-26.4 (26.26±0.12)	25.6-25.9 (25.73±0.12)	24.2-24.8 (24.53±0.25)	22.8-23.5 (23.13±0.29)

Figures in parentheses represent means of three replicates with SD

Control sample heat treatment - 85°C/30 sec; Homogenization pressure - 6.86/3.43 MPa;
Freezing - Traditional method

Melting resistance of kulfi improved with severity of heat treatment. High temperature causes denaturation of milk proteins leading to increased water binding capacity (Flack, 1987).

5.2.7.2 Sensory Properties

The mean flavour scores of kulfi increased with heating of mix at 100°C upto 10 min. Heating of mix for periods longer than 10 min at 100°C was accompanied with low flavour scores (Table 37). These changes in scores were found to be significant at $P < 0.01$ (Table 38). Perception of cooked flavour improved with heat treatments upto 10 min. The samples developed burnt flavour at 100°C for 15 min which was not liked by the panelists. Control samples were criticised for having insufficient cooked flavour.

Body and texture scores of kulfi were significantly influenced by the severity of heat treatment (Table 38). The hard, compact body and fine grainy texture produced by heat coagulation of protein is a characteristic feature of good kulfi. This quality could be achieved after heat treating the mix at 100°C for 10 min. Higher degree of heat treatment produced kulfi with big size coagulated mass which was not liked by the judges. The control samples were devoid of fine grainy texture and got lower scores as compared with the experimental samples.

Kulfi mix samples became brown with increased severity of heat treatment. Heat induced Maillard browning is the principal cause for changes in colour (Table 37). Kulfi samples prepared from the mix heat treated at 100°C for 10 min were judged best in terms of colour and appearance. More severe heat treatment, i.e., 100°C for 15 min produced kulfi with visibly big coagulated milk particles which lowered the appearance scores.

Melting quality of kulfi changed significantly ($P < 0.01$) with the severity of heat treatment (Table 38). Kulfi prepared from mix heat treated

Table 37. Mean sensory scores of kulfi prepared by using different heat treatments

Heat treatments (°C/min)	Sensory attributes			
	Flavour	Body and texture	Colour and appearance	Melting quality
Control	40.70	31.72	7.41	4.30
100/5	44.85	32.90	8.21	4.48
100/10	46.71	34.80	8.54	4.69
100/15	45.50	33.25	8.10	4.12

Table 38. ANOVA for sensory evaluation scores of kulfi prepared by using different heat treatments

Sources of variation	d.f.	Mean sum of squares			
		Flavour	Body and texture	Colour and appearance	Melting quality
Replicates	2	0.0001	0.0002	0.00008	0.00003
Treatments	3	20.4322**	4.9016**	1.5081**	1.8185**
Error	6	0.0001	0.0002	0.0002	0.0003

** Significant at $P < 0.01$

at 100°C for 10 min received the highest score (Table 37). Still higher degree of heat treatment produced kulfi with coagulated milk particles which did not melt easily in the mouth. The control kulfi samples and those prepared from mix heat treated at 100°C for 5 min showed faster melting.

It could be concluded that kulfi prepared with mix heat treated at 100°C for 10 min produces most desirable cooked flavour, fine grainy texture, compact body and optimum melting resistance.

5.2.7.3 Heat Induced Changes In Major Proteins

Milk proteins undergo temperature dependent changes. The heat treatments applied to kulfi mix during manufacture of kulfi caused some alteration in casein structure. These changes were investigated on polyacrylamide gel disc electrophoresis.

Fresh raw buffalo milk casein resolved into 3 bands on the polyacrylamide gel (Plate 3). Electrophoretic mobility of all the casein fractions of kulfi mix subjected to different heat treatments exhibited minor changes. The k-casein band migrating in the vicinity of β-casein of raw milk completely disappeared after heat treatments. Rajorhia (1978) observed that casein fractions other than kappa- are not altered by heat treatment normally employed in khoa making. The conventional method of khoa making involves boiling of buffalo milk vigorously in an open pan for 7-8 min. This time temperature combination brought about very little change in the electrophoretic behaviour of casein. Whey proteins and k-casein are, however, completely denatured during khoa making.

The electrophoretic mobilities of α- and β-caseins isolated from kulfi mix subjected to different heat treatments got slowed down slightly. It is likely that high heat treatments applied to milk components in the manufacture of kulfi, caused aggregation of casein fractions.

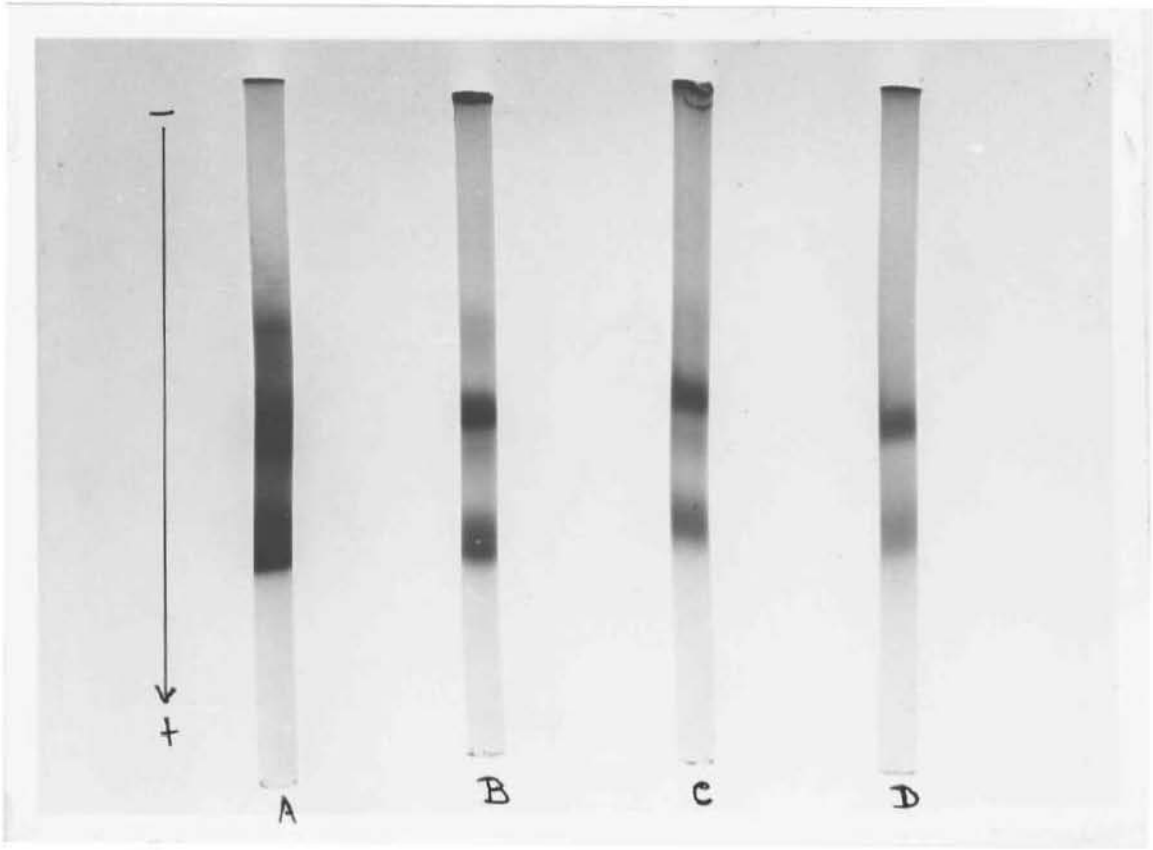
Plate 3 Electrophorogram of proteins of kulfi mix

A - Raw buffalo milk

B - Kulfi mix heated to 100°C for 5 min

C - Kulfi mix heated to 100°C for 10 min

D - Kulfi mix heated to 100°C for 15 min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5.2.8 SELECTION OF SUITABLE FREEZING METHOD

Freezing is one of the most important operations in making kulfi. The mix is quickly frozen while being agitated in such a way as to produce and control formation of the small ice crystals that are necessary to give smooth body and textture, palatability and stiffness. The influence of various freezing methods on kulfi was determined with the help of melt down property and sensory evaluation. The mix was formulated from fat 11.0, MSNF 16.0, sugar 15.0 and isabgol husk 0.2 per cent and heat treated at 100°C for 10 min.

5.2.8.1 Melting Property

As the mix of the same composition was used in different freezing methods, there was no difference in acidity, pH, specific gravity, relative viscosity and surface tension values. The mean values were: acidity 0.28 per cent, pH 6.37, specific gravity 1.1230, relative viscosity 2.41 and surface tension 49.26 dynes/cm . However, different freezing methods exerted some influence on melt down property (Table 39).

Table 39. Effect of different freezing methods on melt down property of kulfi

Characteristic	Methods of freezing			
	Traditional method (Method I)	Brine tank method (Method II)	Batch freezer method (Method III)	Direct hardening method (Method IV)
Kulfi melt down (ml/30 min)	24.3-24.6 (24.47±0.12)	23.9-24.2 (24.03±0.12)	20.8-21.5 (21.20±0.29)	26.8-27.3 (27.07±0.20)

Figures in parentheses represent means of three replicates with SD

Homogenization pressure - 6.86/3.43 MPa

Kulfi mix was partially frozen in mechanical ice cream freezer to ascertain the freezing behaviour. The relationship between the freezing time and per cent overrun has been depicted in Fig. 3. The per cent overrun of kulfi mix increased with time. It attained about 26.0 per cent overrun in 14 min, beyond this point the rate of increase in overrun declined. In the ice cream mixes containing about 36 to 38 per cent TS, an overrun of about 90 per cent is obtained within 5 min (Arbuckle, 1986). Slow rate of overrun attainable in kulfi may be attributed to high MSNF content and denaturation of proteins which markedly depress the air cell stabilizing property of the mix.

It could be observed from Table 39 that batch frozen kulfi (Method III) had the lowest melt down and maximum in method IV. The low melt down of kulfi frozen by methods I, II and III was due to fast and complete freezing. In these cases, the temperature of mix got lowered quickly due to agitation. In method IV, the freezing was done at slow rate because there was no agitation of mix. Quick and complete freezing increases the stiffness of kulfi and helps in producing larger number of small size ice crystals which in turn help to attain smooth texture and greater melting resistance (Salooja, 1979).

5.2.8.2 Sensory Properties

The different methods of freezing significantly affected the flavour scores of kulfi (Table 41). Kulfi frozen in a brine tank (Method II) received the highest score, followed by methods I, III and IV. Fast freezing accompanied by constant agitation in methods I and II helped to produce a smooth and uniform product which melted at moderate rate in the mouth. Method III produced kulfi having soggy body and low flavour score. Kulfi frozen my method IV had big sized ice crystals resulting in very cold sensation in the mouth which adversely affected the flavour scores.

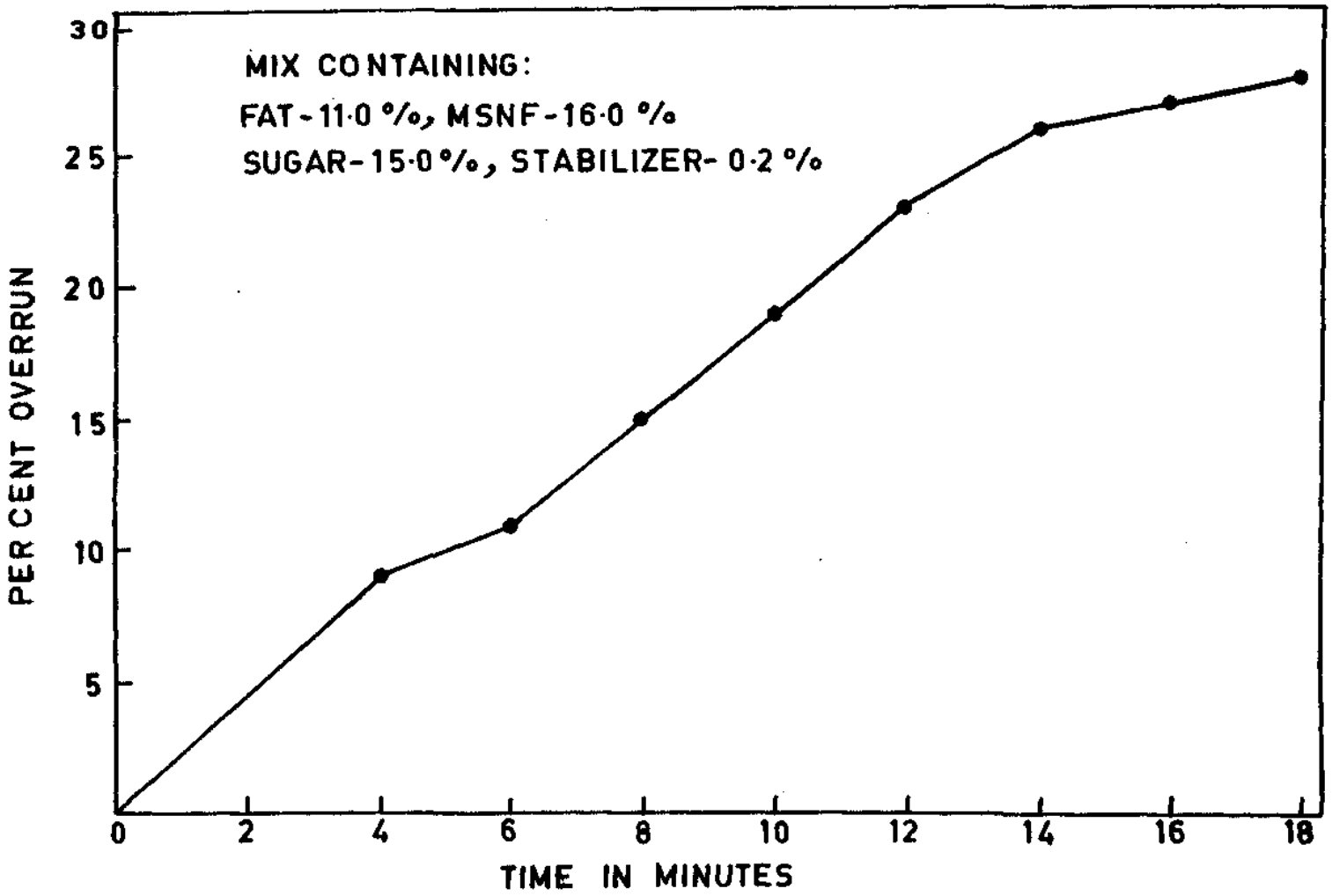


FIG. 3. RELATIONSHIP BETWEEN FREEZING TIME AND PERCENT OVERRUN OF KULFI MIX.

Table 40. Mean sensory scores of kulfi prepared by using different methods of freezing

Methods of freezing	Sensory attributes			
	Flavour	Body and texture	Colour and appearance	Melting quality
I	46.61	33.74	8.10	4.45
II	47.40	34.66	8.15	4.60
III	45.11	31.11	8.00	3.70
IV	42.15	28.72	7.73	3.58

Table 41. ANOVA for sensory evaluation scores of kulfi prepared by using different methods of freezing

Sources of variation	d.f.	Mean sum of squares			
		Flavour	Body and texture	Colour and appearance	Melting quality
Replicates	2	0.0001	0.0002	0.0001	0.0001
Treatments	3	16.0676**	21.6229**	0.3673**	0.9056**
Error	6	0.00004	0.00006	0.0001	0.0003

** Significant at $P < 0.01$

Methods I and II produced kulfi having smooth texture with uniformly distributed fine ice crystals and compact hard body. Although method II produced superior product in terms of body and texture (Table 40), kulfi became soggy and icy in methods III and IV respectively and received lower scores. Brine tank method of freezing was found to be appropriate for commercial production of kulfi.

The creamy white colour with brown tinge remained unaffected with different methods of freezing. The appearance of kulfi changed significantly ($P < 0.01$). In methods I and II, the samples had very glossy appearance which were liked most by the judges (Table 40). Method III produced kulfi having slight wet appearance, which is considered a defect. Kulfi frozen by method IV had uneven distribution of milk solids which were found to concentrate at one end of the cone.

The mean scores for melting quality were found to be significant (Table 41) indicating that the method of freezing greatly influenced this quality. Kulfi frozen by method II received the highest scores (Table 40) followed by methods I, III and IV in descending order. Methods III and IV produced slow and fast melting kulfi respectively, leading to lower scores than others. It could be concluded that brine tank method is most desirable for freezing of kulfi in terms of sensory attributes.

The method developed for industrial production of kulfi is presented in Fig. 4. It may be observed that the process for the manufacture of kulfi standardized in the present investigation would involve: standardization of mix to 11.0 per cent fat, adjustment of MSNF to 16 per cent, sugar 15.0 per cent and isabgol husk 0.20 per cent, homogenization at 6.86/3.43 MPa, heating at 100°C for 10 min, cooling, flavouring, filling in moulds, freezing in brine tank, and hardening at -23° to -25°C.

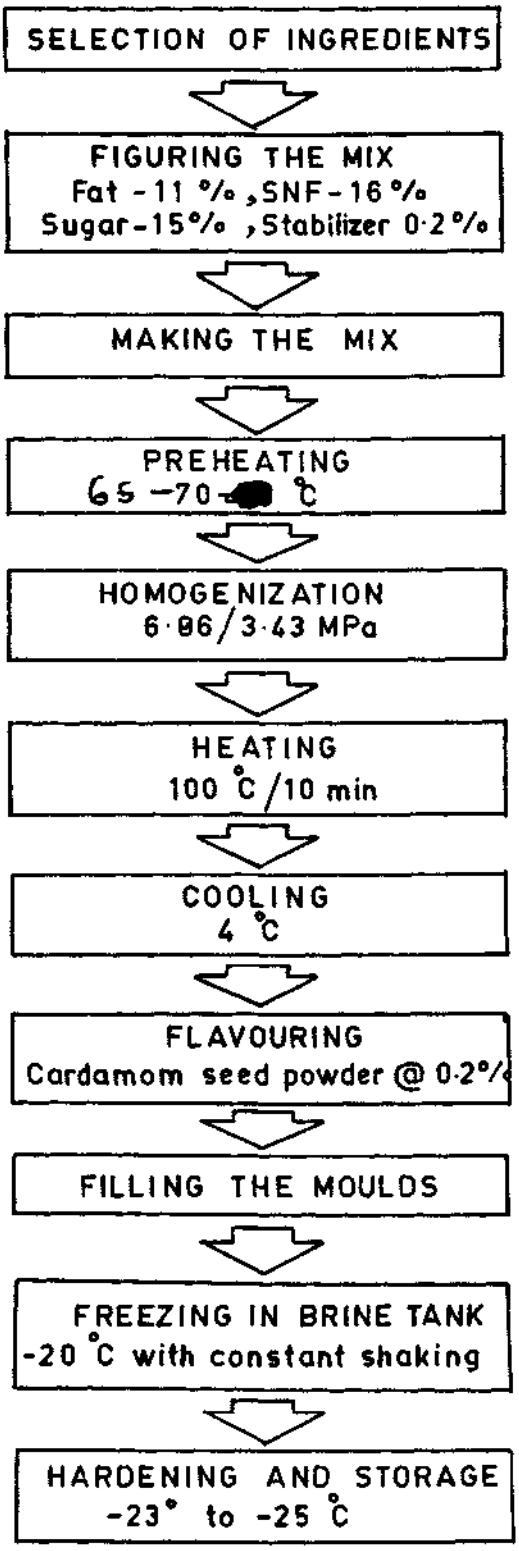


FIG. 4. PROCESS FLOW FOR INDUSTRIAL PRODUCTION OF KULFI

5.3 STANDARDIZATION OF SPRAY DRYING PROCESS FOR KULFI MIX

The technology for production of kulfi mix powder using spray drying process was standardized in respect of total solids concentration of mix (40 and 45 per cent), three inlet and outlet air temperatures and three speeds of atomizer.

5.3.1 DEGREE OF TOTAL SOLIDS CONCENTRATION

The total solids concentration in the mix directly influence the chemical and physical qualities of dried milk products and efficiency of drying. In order to find out the most appropriate TS concentration for spray drying, the composition of kulfi mix containing 11.0 per cent fat, 16.0 per cent MSNF, 15.0 per cent sugar and 0.20 per cent isabgol husk was readjusted in respect of sugar since it was planned to add 25 per cent of the sugar in the mix before drying and dry blend 75.0 per cent of the total sugar with powder. The TS of the mix after readjustment of composition was standardized to 40.0 and 45.0 per cent and pre-heated at 100°C for 10 min to develop cooked flavour. The samples with 45.0 per cent TS got destabilized during preheating at 100°C for 10 min due to thermal denaturation of proteins. It was, therefore, decided to select the lower TS level of 40.0 per cent with the following composition of kulfi mix:

Ingredients	Per cent
Fat	14.25
MSNF	20.65
Sugar	4.84
Isabgol husk	0.26
Total	40.00

5.3.2 OPTIMIZATION OF SPRAY DRYING CONDITIONS

Spray drying conditions such as inlet and outlet air temperatures and speed of atomizer were standardized to obtain a desirable product having optimum bulk density and low moisture content. The influence of different spray drying conditions on the physico-chemical and sensory properties of dried kulfi mix have been depicted in Tables 42 and 43 respectively.

5.3.2.1 Physico-chemical Characteristics

The drying temperatures and atomizer speed were found to influence the particle size of kulfi mix powder. At 190/92°C inlet and outlet drying air temperature and atomizer speed of 25,000 rpm, the mean particle size was 35.17 microns which got reduced to 22.15 and 20.12 microns at 180/85 and 170/80°C temperatures respectively. The size of powder particle can be correlated with sudden moisture expansion within the droplet (Pisecky, 1980; Bhandari and Balachandran, 1984). Under identical drying temperatures, the mean particle size got decreased with an increase in the speed of atomizer due to the formation of fine spray mist (Vilder et al., 1976; Bhandari and Balachandran, 1988).

The atomizer speed significantly influenced the moisture content under identical drying temperatures (Table 42). The decrease in moisture content of powder consequent to increased atomizer speed may be attributed to the greater degree of atomization which caused considerable increase in the surface area of the droplets resulting in rapid evapoaration of water (Vilder et al., 1976; Baldwin et al.,1980). At the lowest drying temperature (170/80°C) the moisture content increased to 3.27, 3.49 and 3.86 per cent at atomizer speeds of 25,000, 20,000 and 15,000 rpm respectively.

It was observed that decreases in drying temperature and atomizer speed caused increase in bulk density of dried kulfi mix. Drying at higher

Table 42. Effects of different spray drying conditions on physico-chemical properties of kulfi mix powder

Inlet/outlet temperature (°C)	Atomizer speed (rpm)	Mean particle size (u)	Moisture (%)	Free fat (%) (fat basis)	Bulk density (g/ml) (with 25% of total sugar)	Bulk density (g/ml) (with 100% of sugar)
	25,000	35.17±0.42	1.65±0.02	16.89±0.02	0.48±0.008	0.54±0.004
190/92	20,000	38.92±0.45	1.89±0.04	17.95±0.04	0.54±0.007	0.58±0.012
	15,000	41.86±0.39	2.05±0.05	18.76±0.04	0.57±0.005	0.63±0.005
	25,000	22.15±0.29	2.28±0.11	14.21±0.02	0.53±0.007	0.65±0.004
180/85	20,000	24.68±0.31	2.51±0.08	15.65±0.02	0.57±0.011	0.68±0.004
	15,000	28.13±0.33	2.76±0.08	16.47±0.03	0.60±0.008	0.71±0.007
	25,000	20.12±0.37	3.27±0.07	12.37±0.03	0.56±0.004	0.67±0.011
170/80	20,000	23.27±0.32	3.49±0.05	13.05±0.02	0.59±0.005	0.70±0.007
	15,000	25.81±0.31	3.86±0.07	13.82±0.04	0.64±0.005	0.72±0.007

Figures represent means of three replicates with SD

inlet temperature causes expansion of air bubbles in the droplets (Hayashi et al., 1970) especially if it takes place at the stage when an overwhelming part of the droplet is still semi-plastic and thus causes a reduction in the bulk density. On the other hand, at higher atomizer speed, mean bulk density got decreased. This may be attributed to increase in vocuole volume in powder particles (Vilder et al., 1976). Dry blending of powder with ground sugar increased the bulk density of the experimental samples by 7.40 to 22.64 per cent. This will provide considerable savings of the packaging materials. The lowest bulk density of 0.54 g/ml was obtained in the finished product dried at an inlet air temperature of 190° and the outlet air temperature of 92°C while maintaining the atomizer speed at 25,000 rpm.

The change in atomizer speed under identical drying temperatures was found to influence the free fat content of kulfi mix powder. The speed of the atomizer exerts some homogenization effect on concentrated milk leading to slight reduction in free fat content in the whole milk powder (Vilder et al., 1976) and malted milk food (Salooja, 1983). Free fat content got increased at elevated temperatures of drying which may be caused by the cracks appearing on the surface of the particles due to over heating (Knipschildt, 1986).

5.3.2.2 Sensory Properties

The kulfi mix powder was evaluated for its sensory characteristics by a panel of judges in accordance with the score card developed (Annexure II). The effects of processing variables on the sensory characteristics have been shown in Table 43.

The change in the speed of atomizer under similar drying temperatures did not cause much effect on flavour scores. Kulfi mix powder produced at drying air temperature of 180°/85°C was rated best followed by the samples

Table 43. Effect of different spray drying conditions on mean sensory scores of kulfi mix powder

Inlet/outlet temperature (°C)	Atomizer speed (rpm)	Flavour	Body and texture	Colour and appearance	Sensory comments
190/92	25,000	6.10	7.21	6.75	Pronounced cooked flavour, sticky body, brown colour (Not acceptable)
	20,000	6.17	7.25	6.72	
	15,000	6.25	7.24	6.68	
180/85	25,000	7.98	8.12	8.35	Moderately cooked flavour, fine texture, slightly brown colour (Acceptable)
	20,000	8.07	8.14	8.30	
	15,000	8.10	8.15	8.28	
170/80	25,000	6.55	6.17	7.18	Slightly cooked flavour, lumpy body, creamy white colour (Not acceptable)
	20,000	6.52	6.21	7.10	
	15,000	6.50	6.19	7.06	

dried at 170°/80°C and 190°/92°C. At elevated drying temperature, the flavour scores got reduced significantly. Such samples had excessive cooked flavour for which the judges commented adversely. Insufficient cooked flavour developed in kulfi mix powder manufactured at 170°/80°C lead to lower ratings.

Drying of kulfi mix at different temperatures had a significant effect on the body and texture scores of the product, while variation in atomizer speed did not cause any appreciable change in the scores. Kulfi mix powder prepared by employing drying air temperature of 180°/85°C was rated best in terms of body and texture, the other two in decreasing order were 170°/80°C and 190°/92°C. Kulfi mix powder became sticky at higher temperature of drying (190°/92°C) probably due to melting of added sugar in the mix, whereas at lower temperature (170°/80°C), the product developed slight lumpy body due to higher moisture content ($>$ 3.0 per cent).

The colour and appearance scores were found to vary significantly with the changes in drying air temperatures. The lowest score awarded to the product manufactured by using 190°/92°C dry air temperature was due to browning as a result of Maillard reaction and sugar caramelization. On the other hand, lower temperature (170°/80°C) failed to produce the desired light brownish colour in the product, hence received lower rating. Under identical drying temperature, the scores slightly improved with the increase in atomizer speed. This could be attributed to the formation of progressively finer particles which in turn had higher light scattering property.

On the basis of physico-chemical and sensory attributes of dried kulfi mix prepared under different spray drying conditions, it could be concluded that product having bulk density in the range of 0.65 to 0.68 g/ml and moisture around 2.50 per cent will have great commercial significance in terms of packaging and shelf-life. The standardized method developed for production of kulfi mix powder by spray drying process has been presented

in Fig. 5. The method involves making the mix containing 25.0 per cent of the total sugar and adjustment of TS to 40.0 per cent, homogenization of the mix at 6.86/3.43 MPa pressure at 70°-75°C, heat treatment in a tubular heat exchanger at 100°C for 10 min, spray drying at 180°C inlet air temperature and 85°C outlet air temperature using 20,000 rpm atomizer speed, dry blending of remaining balance of ground sugar with powder, packaging and storage. The finished product had the following composition (per cent by weight):

Moisture	2.52
Fat	25.41
Total protein	14.56
Lactose	19.43
Sugar	34.65
Ash	2.97
Isabgol	0.46

5.4 SELECTION OF PACKAGING MATERIALS FOR KULFI MIX POWDER

The packaging materials and storage temperature greatly influence the chemical, physical, microbiological and sensory properties of dried milk products. The selection of suitable packaging material for kulfi mix powder was essentially based on former's protective properties. The choice was limited to metallized polyester and tin can since Ranganadham (1988) concluded that among many packages tried for khoa powder, these two packages proved to be ideal.

5.4.1 CHEMICAL PROPERTIES

The initial moisture content in kulfi mix powder was 2.52 per cent. The moisture content increased gradually upto 0.58 per cent at the end of six months storage at 30 ± 1°C in metallized polyester pouches (Table 44).

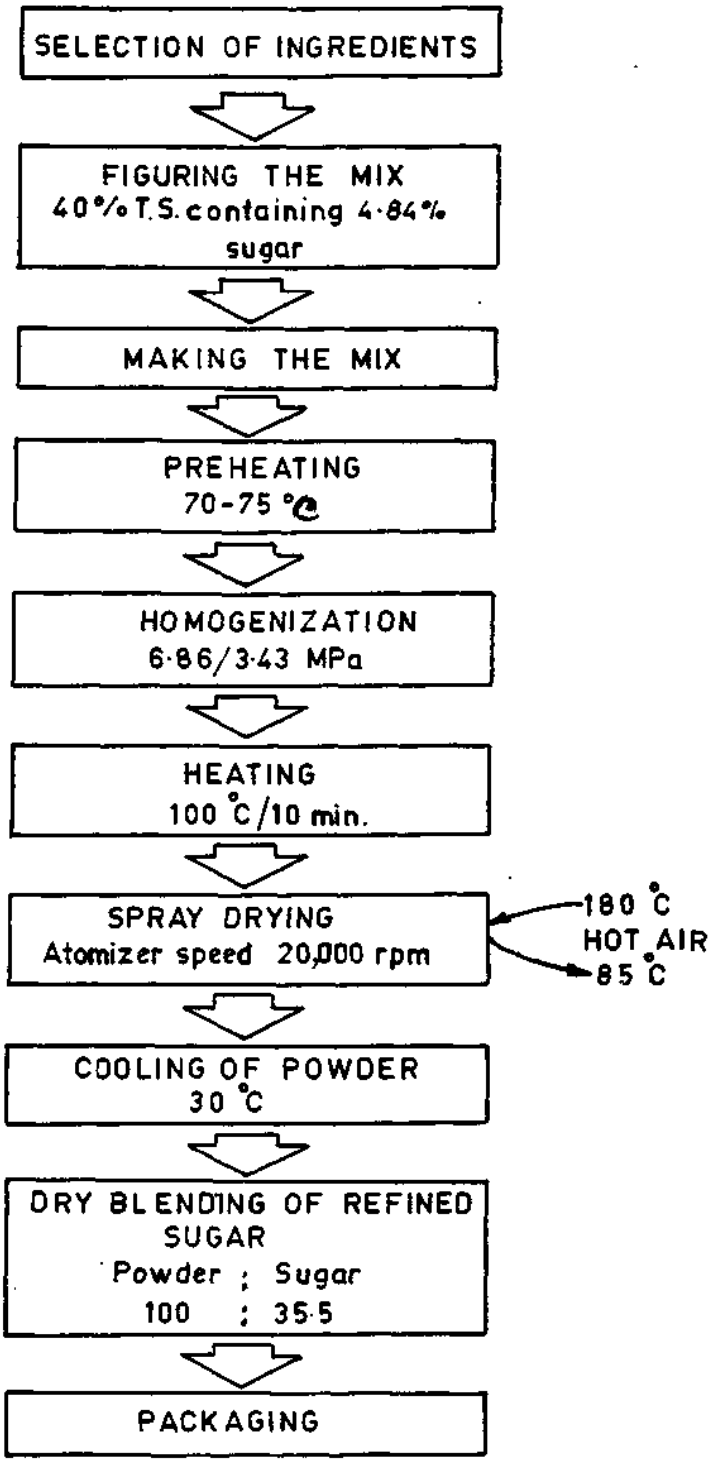


FIG.5. PROCESS FLOW FOR PRODUCTION OF SPRAY DRIED KULFI MIX POWDER

Table 44. Effect of packaging materials on chemical properties of kulfi mix powder during storage at 30 ± 1°C

Packaging materials	Storage period (months)	Moisture (%)	pH	Titratable acidity (% LA)	Free fat (% of total fat)	Peroxide value (meq O_2/kg fat)	FFA (%)	Available lysine (% of total protein)	Lactulose (mg/100 g of sample)
Metallized polyester	Initial	2.52	6.52	1.05	15.65	0.039	0.026	0.93	325.00
	1	2.58	6.49	1.05	16.21	0.048	0.032	0.86	363.00
	2	2.67	6.48	1.08	16.52	0.097	0.038	0.82	410.00
	3	2.79	6.45	1.11	16.87	0.145	0.045	0.75	462.00
	4	2.88	6.42	1.11	17.57	0.188	0.058	0.63	507.00
	5	2.97	6.38	1.15	18.48	0.259	0.088	0.54	569.00
	6	3.10	6.36	1.18	19.15	0.363	0.102	0.43	628.00
Tin cans	1	2.55	6.52	1.05	15.78	0.042	0.028	0.88	352.00
	2	2.59	6.50	1.05	16.10	0.046	0.031	0.84	378.00
	3	2.61	6.48	1.07	16.38	0.087	0.037	0.81	405.00
	4	2.67	6.47	1.09	16.69	0.138	0.042	0.78	442.00
	5	2.72	6.44	1.12	17.10	0.167	0.059	0.69	481.00
	6	2.75	6.42	1.16	17.62	0.211	0.072	0.60	527.00
	7	2.77	6.39	1.16	18.32	0.280	0.086	0.55	585.00
	8	2.81	6.35	1.19	18.96	0.360	0.098	0.46	642.00

Kulfi powder samples packed in tin cans showed an increase of about 0.30 per cent moisture in eight months. The maximum limit prescribed for moisture in ice-cream powder and WMP is 4 per cent. Metallized polyester proved to be less efficient in moisture barrier property than tin cans. Moisture percentage in milk powder may increase either by ingress of water vapours or due to chemical changes occurring during storage. The re-absorption of water released in Maillard reaction could lead to minor increase in moisture (Coulter et al., 1948). A gradual increase in moisture content in dried whole milk during storage was also reported by Mrithyunjaya and Bhanumurthi (1987). The moisture content of dried ice cream powder packed in metallized polyester and tin can increased from 1.82 to 2.47 and 1.79 to 1.94 per cent respectively during storage at 30°C (Bhandari, 1982).

A gradual increase in free fat content, peroxide value and FFA was observed during storage (Table 44). These increases could be affected by the increasing moisture content (Kirst, 1981). With the absorption of moisture, lactose crystallization takes place leading to changes in free fat content (Kopecky, 1978). The rate of increase in total 5-HMF content of kulfi mix powder was slower in samples packed in tin cans (Fig. 6) than those contained in metallized polyester. Browning intermediates continued to increase during progressive storage (Fig. 6). Low moisture content in the product delays the browning reaction. The rate of browning is dependent on the moisture content of the system increasing with an increase in water content (Reynolds, 1963).

The initial titratable acidity (1.05 per cent) showed a slow increase with corresponding decrease in pH values during the storage of kulfi mix powder. Titratable acidity and pH values of khoa powder also changed from 1.08 to 1.11 and 6.70 to 6.60 respectively over a period of eight months storage at 30°C (Ranganadham, 1988).

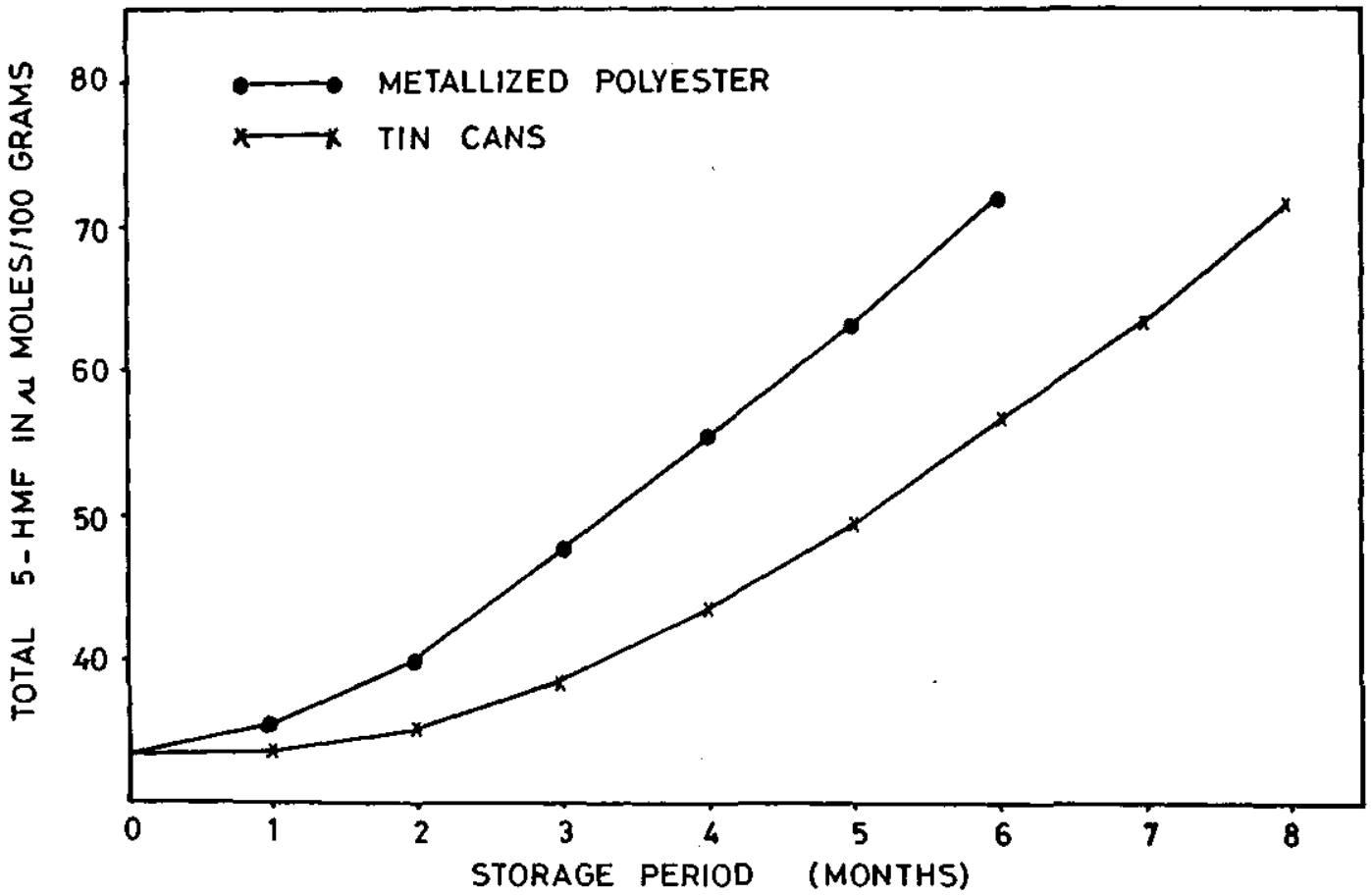


FIG. 6 EFFECT OF PACKAGING MATERIAL ON TOTAL 5-HMF VALUE OF KULFI MIX POWDER DURING STORAGE AT 30 ± 1°C

Available lysine content of fresh kulfi mix powder (0.93 per cent of total protein) got decreased with progressive storage (Table 44). The rate of decrease was faster in samples packed in metallized polyester than those packed in tin cans. The loss of about 50 per cent available lysine during eight months storage in tin containers may be attributed to protein-protein and protein-carbohydrate interactions. Paul (1984) observed that available lysine content decreased from 0.76 to 0.31 per cent in infant milk food after a storage period of 12 months at 37°C. Lactulose (4-O-β-D-galactopyranosyl-D-fructofuronose), an isomer of lactose formed during the heat treatment of milk (Adachi, 1958), was found to increase significantly with the storage period. This increase may be due to either indirect consequence of Maillard reaction or by isomerization of lactose catalysed by the amino group of casein at high storage temperature (Andrews, 1985).

5.4.2 PHYSICAL PROPERTIES

The effect of packaging materials on physical properties of kulfi mix powder is presented in Table 45. There was a gradual loss of solubility, flowability, wettability and dispersibility, whereas bulk density and water activity registered increase during storage at 30°C. The losses in flowability, solubility, dispersibility and wettability were faster in samples packed in metallized polyester pouches than those in tin cans. An increased amount of free fat might be responsible for the loss in wettability and flowability. Inverse relation between free fat content and wettability was reported by Pjanowski et al. (1974). Loss in wettability in both pre-term infant formula and khoa powder after eight months storage at 30°C has been reported by Rao (1985) and Ranganadham (1988) respectively. The changes in protein structure due to Maillard reaction and protein-protein interaction during storage could be responsible for the loss of solubility and

Table 45. Effect of packaging materials on physical properties of kulfi mix powder during storage at 30 ± 1°C

Packaging materials	Storage period (months)	Bulk density (g/ml)	Flow-ability (Tan θ)	Wetta-bility (sec)	Solubility index (ml)	Dispersi-bility (g)	Water activity (a_w)
Metallized polyester	Initial	0.68	58.10	30.20	1.20	28.90	0.250
	1	0.69	58.80	30.80	1.30	28.80	0.252
	2	0.71	60.20	33.50	1.40	28.60	0.253
	3	0.71	60.80	35.40	1.60	28.30	0.255
	4	0.73	62.30	36.20	1.70	28.00	0.258
	5	0.76	64.20	38.30	1.80	27.50	0.264
	6	0.79	66.40	40.20	2.00	26.80	0.271
Tin cans	1	0.68	58.50	30.40	1.20	28.80	0.252
	2	0.68	58.50	31.50	1.30	28.70	0.253
	3	0.70	60.10	33.20	1.40	28.50	0.254
	4	0.70	61.30	34.50	1.50	28.10	0.256
	5	0.73	62.10	35.30	1.60	27.70	0.259
	6	0.74	63.20	36.50	1.70	27.40	0.261
	7	0.76	64.40	38.40	1.90	26.90	0.265
	8	0.78	65.70	40.50	2.00	26.50	0.270

dispersibility (Colos and Segena, 1979). A slight reduction in dispersibility from 32.9 to 31.6 g was observed in malted milk food after a storage period of 12 months at 30°C (Salooja, 1983). An increase in solubility index from 1.2 to 2.0 ml was reported for spray dried khoa powder stored at 30°C for eight months (Ranganadham, 1988).

Bulk density of kulfi mix powder increased with the storage period irrespective of packaging materials used. Increase in bulk density with increased moisture content was also observed by Kerekreti (1980) and Bhandari (1982) in dried milk and ice cream mix powder respectively. An increase in bulk density may be attributed to increased cohesiveness caused by absorption of moisture during storage. The a_w of kulfi mix powder was 0.25 on initial day which increased to 0.27 after storage for eight months at 30°C. A gradual moisture penetration into the product and release of water due to various chemical reactions taking place in the milk components might have increased the a_w of the stored product. Similar observations were made by Ranganadham (1988) during storage of khoa powder at 30°C.

The reflectance value of kulfi mix powder was found to decrease with storage period (Fig. 7). These changes may be attributed to the formation of melanoidins as a result of Maillard reaction. Paul (1984) also reported similar change in reflectance values of infant milk food after storage for 12 months at 37°C.

5.4.3 MICROBIOLOGICAL QUALITY

The microbial counts in fresh kulfi mix powder on an average were TVC 18.5×10^3, staphylococcal count 7.2×10^2 and yeast and mould count 63 per g of product. The microbial counts largely depend upon the quality of raw materials used in the product preparation and the methods of processing.

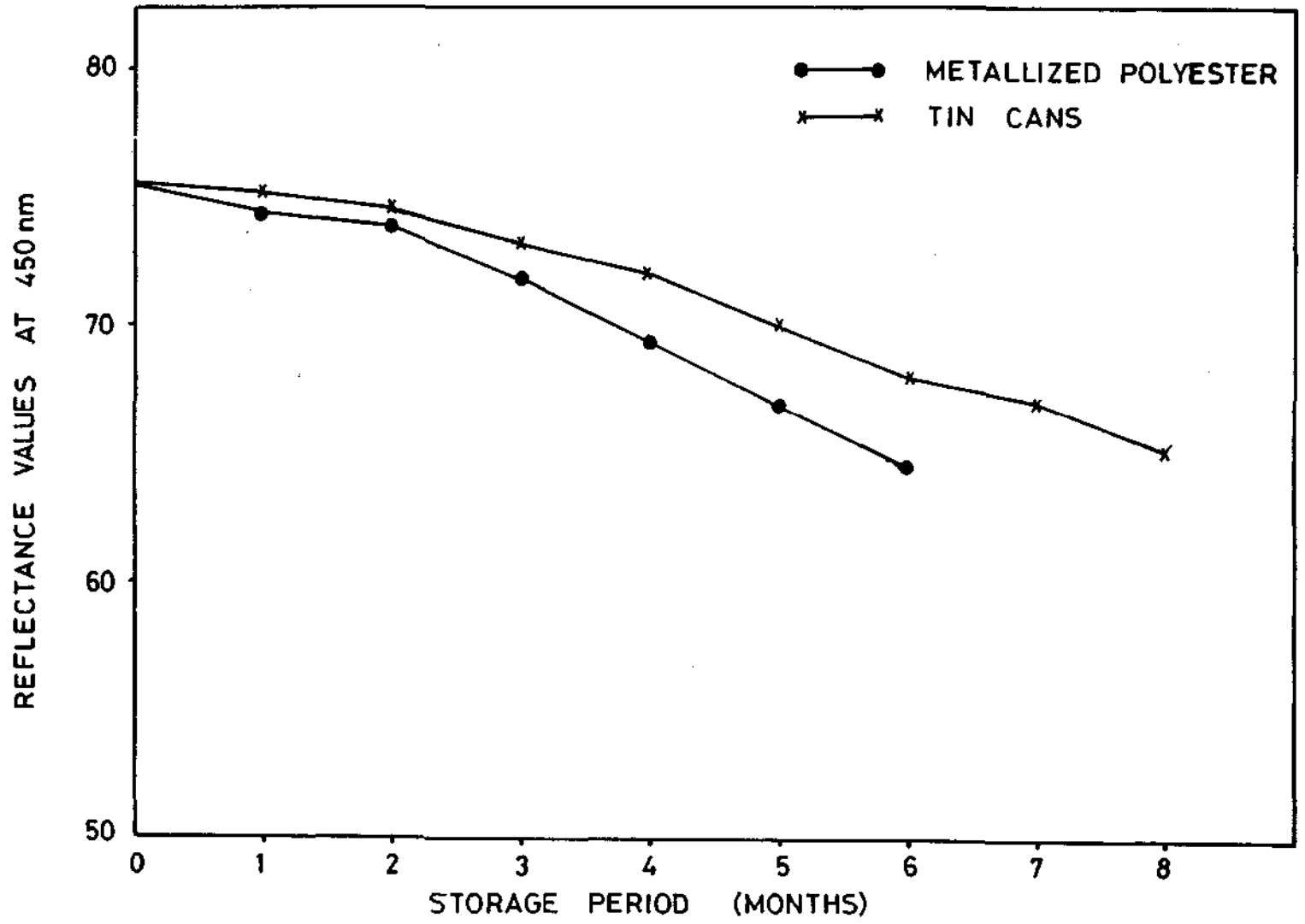


FIG. 7 EFFECT OF PACKAGING MATERIALS ON REFLECTANCE OF KULFI MIX POWDER DURING STORAGE AT 30 ± 1° C.

Table 46. Influence of packaging materials on microbiological quality of kulfi mix powder during storage at 30 ± 1°C

Packaging materials	Storage period (months)	TVC $x10^3$	Staphylococcal count $x10^2$	Yeast and Mould count $x10^1$
Metallized polyester	Initial	18.5	7.2	6.3
	1	16.5	6.1	5.1
	2	14.8	5.7	4.0
	3	11.2	4.4	2.0
	4	8.1	3.2	1.6
	5	6.3	2.4	1.0
	6	4.1	1.1	0.6
Tin cans	1	15.9	6.4	5.4
	2	12.2	5.5	4.2
	3	9.6	4.5	3.0
	4	7.6	3.1	2.2
	5	6.2	2.6	1.0
	6	4.4	1.4	0.7
	7	3.2	0.8	0.5
	8	2.6	0.2	0.2

Note: Coliforms were absent

TDNase negative in all samples

Variations in microbiological quality of kulfi mix powder manufactured under industrial situation may be expected due to other factors like temperature and duration of storage, methods of handling, etc.

The type of package and storage period showed significant influence on the survival of microorganisms in kulfi mix powder (Table 46). Whereas, yeast and mould counts decreased rapidly during storage, staphylococci exhibited greater survival. Low water activity in the product coupled with antimicrobial nature of some chemical compounds formed during Maillard reaction could cause rapid destruction of microbial cells during storage (Lara and Gilliland, 1985). All the kulfi mix powder samples were found to be free from coliform bacteria. In spray dried SMP also, the standard plate counts decreased from 1.2×10^5 to 1.8×10^4 after six months of storage at room temperature (Arun et al., 1979). TVC in khoa powder got decreased from 17.5×10^3 to 2.5×10^3 after eight months storage at 30°C (Ranganadham, 1988).

5.4.4 SENSORY QUALITY

Packaging materials and period of storage had marked influence on sensory attributes of kulfi mix powder (Table 47). The flavour of samples packed in metallized polyester pouches and tin cans did not deteriorate markedly upto six and seven months respectively. The loss in flavour scores was largely attributed to oxidation of fat. High fat content in dried milk products favours oxidation of unsaturated fatty acids during storage leading to the formation of aldehydes and ketones which are potential off flavour developers (Radayeva et al., 1974). The gradual decrease in body and texture scores in kulfi mix powder samples packed in both the packages was basically due to formation of small powder granules. This defect develops due to increases in moisture and free fat content which in turn would increase the

Table 47. Effect of packaging materials on sensory attributes of kulfi mix powder during storage at 30 ± 1°C

Packaging materials	Storage period (months)	Flavour	Body and texture	Colour and appearance
Metallized polyester	Initial	8.0	8.1	8.1
	1	7.8	7.9	7.8
	2	7.7	7.8	7.7
	3	7.5	7.7	7.5
	4	7.1	7.7	7.3
	5	6.9	7.3	7.0
	6	6.5	6.8	6.7
Tin cans	1	7.9	7.8	7.9
	2	7.8	7.7	7.8
	3	7.7	7.8	7.7
	4	7.4	7.8	7.4
	5	7.2	7.5	7.1
	6	6.9	7.3	6.9
	7	6.6	7.1	6.8
	8	6.4	6.7	6.6

cohesiveness of the powder during storage. The intensity of brown colour increased with the storage period as a result of browning reaction and caused reduction in colour scores.

5.4.5 PHYSICO-CHEMICAL PROPERTIES OF RECONSTITUTED KULFI MIX

The stored dried kulfi mix samples were reconstituted at monthly intervals upto eight months storage. The physico-chemical properties of reconstituted kulfi mix are presented in Table 48.

Titratable acidity of kulfi mix reconstituted from kulfi mix powder increased and pH decreased with advancing storage period. The changes were faster in samples packed in metallized polyester pouches than those in tins. The amino groups of protein get blocked in the Maillard reaction leading to decreased pH (Coulter et al., 1948; Ranganadham, 1988).

There was slight decrease in the specific gravity of reconstituted kulfi mix over the entire storage period. Increase in moisture content during storage reduced the TS content of kulfi mix powder which in turn lowered the specific gravity.

The storage period and packaging materials significantly affected the relative viscosity of reconstituted kulfi mix powder. Relative viscosity of mix prepared from freshly produced powder was 2.39. It decreased to 2.08 for samples in metallized polyester and 2.10 for those in tin cans after a storage period of six and eight months respectively. Proteins take part in the browning phenomenon leading to destabilization during storage (Coulter et al., 1948). Reduction in viscosity of reconstituted ice cream mix after storage was also reported by Bhandari and Balachandran (1984).

Surface tension values of reconstituted kulfi mix decreased steadily with the progress of storage period in both the packaging materials. Release

Table 48. Effect of packaging materials on physico-chemical properties of reconstituted kulfi mix prepared from stored kulfi powder

Characteristics	Packaging materials	Storage period (months)								
		Initial	1	2	3	4	5	6	7	8
Acidity (% LA)	1	0.280	0.280	0.284	0.287	0.290	0.296	0.305		
	2	0.280	0.280	0.281	0.283	0.285	0.288	0.292	0.296	0.302
pH	1	6.36	6.36	6.37	6.33	6.31	6.29	6.27		
	2	6.36	6.37	6.37	6.34	6.33	6.31	6.30	6.28	6.26
Specific gravity	1	1.1232	1.1232	1.1230	1.1227	1.1223	1.1219	1.1214		
	2	1.1232	1.1233	1.1231	1.1230	1.1228	1.1224	1.1221	1.1218	1.1216
Relative viscosity	1	2.39	2.39	2.38	2.32	2.27	2.20	2.08		
	2	2.39	2.39	2.39	2.35	2.30	2.27	2.22	2.17	2.10
Surface tension (dynes/cm)	1	49.00	48.92	48.85	48.79	48.70	48.57	48.49		
	2	49.00	48.95	48.91	48.86	48.81	48.74	48.66	48.59	48.52
Kulfi melt down (ml/30 min)	1	24.5	24.5	24.8	29.4	30.0	30.8	40.6		
	2	24.5	24.4	24.6	29.1	29.5	30.2	30.8	40.5	50.3

Package No. 1 was metallized polyester and No. 2 the tin cans

of free fat, serving as a strong surface active agent during storage might have depressed the surface tension of the mix (Sherbon, 1988).

The period of storage and packaging material markedly affected the melt down quality of kulfi. Protein destabilization associated with prolonged storage at high temperature probably reduced the water binding capacity which in turn decreased the melting resistance of kulfi.

5.4.6 SENSORY QUALITY OF RECONSTITUTED KULFI

The sensory scores of kulfi samples prepared from stored reconstituted kulfi mix powder were significantly different from those of the samples prepared from fresh kulfi mix powder (Table 49).

The flavour scores of reconstituted kulfi decreased steadily with the progress of storage period. The rate of deterioration was slightly faster in samples packed in metallized polyester packs than those in tins. The rapid decline in flavour scores after five months storage could be expected due to oxidative changes (Radayeva et al., 1974). Staleness and browning of dried ice cream mix during storage were found to reduce flavour scores (Bhandari and Balachandran, 1984).

The body and texture scores also decreased with increased storage period. Kulfi samples prepared from five months old dried mix resulted in a crumbly body and gradually became coarse. An icy texture developed in kulfi samples prepared after eight months storage of the mix in tin cans. These defects could be attributed to protein destabilization of dried kulfi mix during storage.

There was a steady reduction in colour and appearance scores of kulfi prepared from stored reconstituted kulfi mix. The light brownish colour of freshly prepared kulfi mix powder turned gradually darker due to Maillard

Table 49. Effect of packaging materials on sensory scores of reconstituted kulfi prepared from powder stored at 30 ± 1°C

Sensory attributes	Packaging materials	Storage period (months)								
		Initial	1	2	3	4	5	6	7	8
Flavour	1	46.5	46.0	45.0	43.6	41.1	38.8	35.5		
	2	46.5	46.3	45.3	44.1	42.6	40.2	39.1	36.0	32.3
Body and texture	1	33.0	32.4	31.5	29.7	28.4	26.6	24.3		
	2	33.0	32.3	31.8	30.4	29.2	28.5	27.1	25.0	23.5
Colour and appearance	1	8.2	8.0	7.7	7.2	6.7	6.0	5.1		
	2	8.2	8.0	7.9	7.5	6.9	6.2	5.8	5.0	4.3
Melting quality	1	4.5	4.5	4.3	4.2	4.0	3.8	3.5		
	2	4.5	4.5	4.5	4.3	4.3	4.1	3.9	3.7	3.4

Package No. 1 was metallized polyester and No. 2 the tin cans

browning. Moreover, the smooth glossy appearance of kulfi changed into a dull appearance which is considered as a storage defect in kulfi mix powder.

Kulfi samples prepared from kulfi mix powder stored for five months melted faster with a slight curdy melt down which could be attributed to destabilization of protein system in the dried mix.

It may be concluded that kulfi mix powder packed in tin containers and metallized polyester can be preserved for seven and six months respectively at 30°C. This shelf life was achieved without addition of any preservative or antioxidants. The shelf-life of kulfi mix could be extended by the addition of preservatives and by refrigerated storage.

5.5 EXTENSION OF SHELF-LIFE OF KULFI MIX POWDER

In the packaging studies (section 5.4) it was inferred that kulfi mix powder packed in tin containers can be preserved for seven months at 30 ± 1°C. Oxidation of fat was the major limiting factor in the shelf-life of dried milk product. Inert gas packaging is recommended in the literature to minimize this defect. Use of antioxidant such as BHA is also known to prolong the shelf-life of high fat dried milk products. In order to market kulfi mix powder nationally and overseas, a longer shelf-life will be desirable. Attempts were, therefore, made to explore the possibility of extending the shelf-life of kulfi mix powder beyond seven months by using a permitted anti-oxidant and nitrogen gas flushing.

5.5.1 USE OF BHA AND NITROGEN GAS PACKAGING ON SHELF-LIFE

A comparative study was conducted to find out the role of BHA and nitrogen gas packaging in preventing the chemical and sensory deterioration of kulfi mix powder at 30°± 1°C. The influence of BHA and inert gas packaging on the microbiological population of kulfi mix powder was also investigated.

Table 50. Effect of BHA and nitrogen gas packing on chemical quality of kulfi mix powder on storage at 30° ± 1°C

Treatments	Storage period (months)	Moisture (%)	pH	Titratable acidity (% LA)	Free fat (% of total fat)	Peroxide value (meq O_2/ kg fat)	FFA (%)	5-HMF value (umoles/ 100 g sample)	Availble lysine (% of total protein)
	Initial	2.58	6.55	1.07	15.70	0.037	0.028	34.02	0.91
	1	2.58	6.55	1.07	15.81	0.040	0.030	34.18	0.89
	2	2.61	6.52	1.08	16.20	0.043	0.034	35.30	0.85
	3	2.64	6.51	1.09	16.42	0.082	0.039	37.59	0.80
Control	4	2.66	6.48	1.09	16.68	0.126	0.044	42.29	0.78
	5	2.70	6.45	1.10	17.20	0.165	0.057	49.18	0.68
	6	2.75	6.44	1.10	17.70	0.223	0.075	57.16	0.59
	7	2.80	6.42	1.11	18.40	0.292	0.084	62.27	0.53
	8	2.84	6.40	1.13	19.10	0.367	0.098	70.25	0.48
	1	2.58	6.55	1.07	15.75	0.039	0.028	34.10	0.90
	2	2.60	6.55	1.08	15.92	0.040	0.029	34.82	0.87
	3	2.62	6.52	1.08	16.15	0.042	0.032	35.10	0.86
BHA	4	2.65	6.50	1.09	16.32	0.048	0.036	36.92	0.82
0.01 per cent	5	2.68	6.49	1.09	16.51	0.054	0.041	40.14	0.80
	6	2.72	6.49	1.10	16.82	0.072	0.045	46.24	0.74
	7	2.76	6.47	1.11	17.42	0.094	0.051	52.13	0.65
	8	2.79	6.45	1.11	17.87	0.122	0.059	57.28	0.60
	9	2.81	6.42	1.12	18.38	0.147	0.068	63.33	0.56

contd.....

contd.... table 50

Treatments	Storage period (months)	Moisture (%)	pH	Titratable acidity (% LA)	Free fat (% of total fat)	Peroxide value (meq O_2/ kg fat)	FFA (%)	5-HMF value (umoles/ 100 g sample)	Available lysine (% of total protein)
Nitrogen gas packing	1	2.58	6.55	1.07	15.70	0.037	0.028	34.08	0.90
	2	2.58	6.55	1.07	15.85	0.037	0.028	34.17	0.90
	3	2.60	6.53	1.08	15.98	0.039	0.029	34.49	0.88
	4	2.62	6.52	1.08	16.10	0.040	0.031	34.97	0.86
	5	2.65	6.52	1.09	16.26	0.045	0.035	35.51	0.84
	6	2.68	6.51	1.09	16.39	0.056	0.040	39.87	0.82
	7	2.71	6.48	1.09	16.72	0.068	0.043	44.71	0.77
	8	2.74	6.45	1.11	16.89	0.085	0.049	50.15	0.68
	9	2.78	6.42	1.12	17.43	0.117	0.055	56.83	0.62
	10	2.81	6.40	1.12	17.97	0.134	0.063	62.73	0.58
BHA 0.01 per cent + nitrogen gas packing	1	2.58	6.55	1.07	15.71	0.037	0.028	34.05	0.90
	2	2.58	6.55	1.07	15.82	0.037	0.028	34.08	0.90
	3	2.59	6.54	1.07	15.93	0.038	0.029	34.15	0.89
	4	2.61	6.52	1.08	16.10	0.038	0.029	34.59	0.88
	5	2.63	6.52	1.08	16.20	0.042	0.032	35.12	0.86
	6	2.65	6.51	1.09	16.29	0.050	0.036	38.57	0.83
	7	2.69	6.49	1.09	16.55	0.062	0.041	42.15	0.79
	8	2.72	6.49	1.09	16.72	0.078	0.047	47.25	0.72
	9	2.75	6.46	1.10	17.12	0.098	0.052	52.13	0.65
	10	2.78	6.43	1.11	17.54	0.121	0.059	57.07	0.62
	11	2.80	6.41	1.12	17.87	0.141	0.064	62.28	0.58

5.5.1.1 Chemical Quality

Addition of BHA, nitrogen gas flushing and their combination slowed down the chemical changes related to oxidative mechanism. Nitrogen gas packing was more effective in delaying the oxidative deterioration of kulfi mix powder than BHA (Table 50). At the end of eight months storage, samples treated with BHA showed a peroxide value of 0.122 whereas the untreated samples registered a steep rise in the peroxide value upto 0.367 meq O_2/kg fat. Nitrogen gas flushing significantly arrested the peroxide formation. The combination of BHA and nitrogen reduced the peroxide formation by 78.0 per cent at the end of eight months storage at 30° ± 1°C. Similar observations were made by Ranganadham (1988) in spray dried khoa powder where peroxide values got reduced by 62.0, 67.0 and 71.0 per cent in samples treated with BHA, nitrogen gas and combination of BHA and nitrogen gas respectively at the end of eight months storage. In the present investigation, BHA prevented hydrolysis of fat, but nitrogen gas flushing was more effective against FFA production. Both free fat content and browning intermediates in untreated samples were significantly higher than the treated samples at any given time of storage. No significant changes in moisture, pH and titratable acidity due to BHA or nitrogen gas packing were observed. These findings are similar to those of Rangandham (1988) for khoa powder examined under identical conditions.

5.5.1.2 Microbiological Quality

The death rate of microbial cells was slowed down in kulfi mix powder samples added with BHA and packed in the presence of nitrogen gas (Table 51). BHA and nitrogen gas delay the chemical reactions by eliminating free oxygen from the product. A chemical free environment may be less detrimental to growth of bactera. Yeast and mould counts declined rather drastically in

Table 51. Influence of BHA and nitrogen gas packing on microbiological quality of kulfi mix powder on storage at 30° ± 1°C

Treatments	Storage periods (months)	TVC $x10^3$	Staphylococcal count $x10^2$	Yeast and mould count x10
Control	Initial	18.5	8.7	6.8
	1	15.6	6.4	5.6
	2	13.4	5.6	4.8
	3	10.3	4.8	3.5
	4	7.8	3.7	2.2
	5	6.4	2.9	1.0
	6	4.4	1.6	0.8
	7	3.2	0.9	0.6
	8	2.7	0.3	0.4
BHA 0.01 per cent	1	15.8	6.9	5.6
	2	13.5	6.1	4.6
	3	10.2	5.5	3.4
	4	7.5	4.3	2.3
	5	6.2	3.7	1.5
	6	5.3	2.6	0.9
	7	4.7	1.3	0.8
	8	3.6	0.8	0.7
	9	2.8	0.5	0.4
Nitrogen gas packing	1	15.8	7.1	5.0
	2	13.6	6.5	3.7
	3	12.2	5.9	3.1
	4	10.5	4.8	2.2
	5	8.7	4.2	1.3
	6	6.3	2.9	0.9
	7	5.3	1.7	0.7
	8	4.5	1.1	0.5
	9	3.7	0.7	0.1
	10	2.8	0.5	nil
BHA 0.01 per cent + nitrogen gas packing	1	16.1	7.4	4.8
	2	14.2	6.8	4.0
	3	12.0	6.2	2.9
	4	10.8	5.4	2.3
	5	9.1	4.8	1.4
	6	8.2	3.2	1.0
	7	6.7	2.7	0.8
	8	5.1	1.6	0.6
	9	3.6	1.0	0.5
	10	3.0	0.7	0.2
	11	2.6	0.4	nil

Note: Coliforms were absent, TDNase negative in all samples

samples packed with nitrogen gas. Yeasts and moulds have greater dependence for oxygen than the bacterial cells. Similar effects were also observed by Ranganadham (1988) during storage of khoa powder treated with BHA and nitrogen gas.

5.5.1.3 Sensory Quality

Addition of BHA and nitrogen gas packing significantly retarded the fall of sensory scores of kulfi mix powder during storage (Table 52). BHA improved the flavour ratings of kulfi mix powder by an additional storage period of 30 days over the control samples. Nitrogen gas was more effective in maintaining the flavour at acceptable level as compared with BHA. A combination of BHA and nitrogen gas proved to be the most beneficial in extending the shelf-life of kulfi mix powder upto 10 months. Improvements in sensory scores could be achieved by slow rate of chemical deterioration of kulfi mix powder during storage, specially the oxidation of fat.

5.5.2 EFFECT OF CARDAMOM ON SHELF-LIFE

Cardamom is known to improve the flavour and palatability of foods. The aromatic compounds in cardamom may also exert antimicrobial influence. Since cardamom is quite popular as a natural flavouring agent, its role in extending the shelf-life of kulfi mix powder was studied. Cardamom powder was uniformly mixed to kulfi powder samples before packing. The control samples did not carry any cardamom. The samples stored at 30° ± 1°C were analysed for changes in chemical, microbiological and sensory properties at one month interval.

5.5.2.1 Chemical Quality

The effect of cardamom seed powder on the chemical quality of kulfi mix powder during storage has been depicted in Table 53. A dose of 0.1

Table 52. Influence of BHA and nitrogen gas packing on sensory quality of kulfi mix powder on storage at 30° ± 1°C

Treatments	Storage period (months)	Flavour	Body and texture	Colour and appearance
Control	Initial	8.0	7.9	7.9
	1	7.9	7.8	7.9
	2	7.8	7.8	7.8
	3	7.7	7.8	7.7
	4	7.4	7.8	7.5
	5	7.2	7.6	7.2
	6	6.9	7.3	6.9
	7	6.6	7.0	6.8
	8	6.3	6.7	6.5
BHA 0.01 per cent	1	8.0	7.9	7.9
	2	7.9	7.8	7.9
	3	7.8	7.8	7.8
	4	7.7	7.8	7.6
	5	7.5	7.6	7.4
	6	7.3	7.6	7.2
	7	6.8	7.5	6.9
	8	6.6	7.1	6.7
	9	6.1	6.9	6.5
Nitrogen gas packing	1	8.0	7.9	7.9
	2	8.0	7.9	7.9
	3	7.9	7.9	7.8
	4	7.9	7.9	7.7
	5	7.7	7.8	7.6
	6	7.6	7.8	7.3
	7	7.3	7.5	7.1
	8	6.8	7.1	6.9
	9	6.5	6.6	6.5
	10	6.1	6.1	6.0
BHA 0.01 per cent + nitrogen gas packing	1	8.0	7.9	7.9
	2	8.0	7.9	7.9
	3	8.0	7.9	7.9
	4	7.9	7.8	7.8
	5	7.8	7.8	7.7
	6	7.7	7.6	7.5
	7	7.4	7.3	7.3
	8	7.0	7.1	7.1
	9	6.7	6.9	6.8
	10	6.5	6.5	6.4
	11	6.3	6.2	6.0

Table 53. Effect of incorporation of cardamom seed powder on the chemical quality of kulfi mix powder stored at 30° ± 1°C

Treatments	Storage period (months)	Moisture (%)	pH	Titratable acidity (% LA)	Free fat (% of total fat)	Peroxide value (meq O_2/ kg fat)	FFA (%)	5-HMF value (umoles/ 100 g sample)	Available lysine (% of total protein)
Control	Initial	2.60	6.55	1.07	15.70	0.037	0.026	34.08	0.92
	1	2.60	6.55	1.07	15.78	0.039	0.029	34.27	0.90
	2	2.61	6.52	1.08	16.31	0.043	0.032	35.46	0.86
	3	2.63	6.50	1.09	16.44	0.087	0.037	37.43	0.82
	4	2.65	6.48	1.09	16.65	0.126	0.048	41.98	0.79
	5	2.69	6.45	1.10	17.10	0.167	0.055	48.92	0.70
	6	2.75	6.45	1.10	17.70	0.225	0.078	56.87	0.61
	7	2.78	6.42	1.12	18.57	0.281	0.084	62.58	0.54
	8	2.81	6.40	1.13	19.28	0.373	0.095	70.25	0.47
Cardamom 0.1 per cent	1	2.59	6.55	1.07	15.75	0.039	0.029	34.27	0.90
	2	2.60	6.52	1.08	16.33	0.044	0.032	35.42	0.86
	3	2.62	6.50	1.09	16.47	0.085	0.036	37.51	0.83
	4	2.65	6.49	1.09	16.61	0.117	0.046	41.88	0.79
	5	2.69	6.45	1.10	16.96	0.169	0.059	49.15	0.69
	6	2.73	6.44	1.10	17.60	0.221	0.074	54.27	0.64
	7	2.78	6.42	1.12	18.42	0.278	0.089	62.74	0.55
	8	2.80	6.41	1.13	19.09	0.368	0.098	70.39	0.48

contd.....

contd.... table 53

Treatments	Storage period (months)	Moisture (%)	pH	Titratable acidity (% LA)	Free fat (% of total fat)	Peroxide value (meq O_2/ kg fat)	FFA (%)	5-HMF value (u moles/ 100 g sample)	Available lysine (% of total protein)
	1	2.59	6.55	1.07	15.71	0.037	0.027	34.25	0.90
	2	2.60	6.52	1.08	16.15	0.042	0.030	35.37	0.85
	3	2.62	6.51	1.09	16.32	0.076	0.032	37.62	0.82
Cardamom	4	2.64	6.49	1.09	16.55	0.105	0.040	42.13	0.78
0.2	5	2.68	6.46	1.10	16.71	0.157	0.053	48.87	0.70
per cent	6	2.73	6.44	1.10	17.32	0.203	0.069	55.17	0.65
	7	2.78	6.42	1.12	17.87	0.262	0.078	62.27	0.56
	8	2.80	6.42	1.13	18.37	0.305	0.085	68.15	0.50
	9	2.83	6.40	1.13	19.21	0.382	0.095	73.87	0.46
	1	2.59	6.55	1.07	15.70	0.037	0.026	34.30	0.90
	2	2.60	6.52	1.08	15.92	0.039	0.030	35.40	0.86
	3	2.62	6.51	1.09	16.17	0.052	0.032	36.95	0.83
Cardamom	4	2.64	6.49	1.09	16.30	0.078	0.035	43.07	0.78
0.3	5	2.68	6.46	1.10	16.58	0.115	0.046	48.51	0.70
per cent	6	2.74	6.44	1.10	16.92	0.155	0.058	54.83	0.66
	7	2.76	6.42	1.12	17.45	0.196	0.065	63.12	0.55
	8	2.78	6.42	1.12	17.97	0.257	0.076	67.38	0.51
	9	2.80	6.41	1.13	18.51	0.315	0.087	72.56	0.46
	10	2.81	6.41	1.13	19.42	0.396	0.098	78.35	0.41

per cent cardamom did not slow down the chemical reactions occurring during storage of kulfi mix powder. However, higher dosage, viz., 0.2 and 0.3 per cent significantly diminished the rate of chemical deterioration. The peroxide formation at the end of eight months storage was lessened by 18.0 and 31.0 per cent in the samples treated with 0.2 and 0.3 per cent cardamom respectively. The rate of increase in free fat content of kulfi mix powder during storage got reduced with increased levels of cardamom. The fine cardamom powder partially coats the outer surface of particles of kulfi mix powder preventing the liberation of free fat. There was a slight increase in moisture, titratable acidity, FFA and browning intermediate and decrease in pH in the samples of kulfi mix powder added with cardamom. No change was observed in the contents of available lysine consequent to addition of cardamom.

5.5.2.2 Microbiological Quality

The different quantities of cardamom in kulfi mix powder had a marked influence on its microbiological quality (Table 54). Higher the level of cardamom higher was the protection offered. Powder samples treated with 0.3 per cent cardamom showed the presence of minimum microbial numbers. Similar observations were reported by Sen (1987) in sandesh where microbial counts decreased with the increase in cardamom level. Staphylococci and yeast and mould cells died off after storage for ten and nine months respectively in samples treated with 0.3 per cent cardamom. The reduction in microbiological counts may be attributed to the reported antiseptic property of aromatic compounds of cardamom (Obe, 1973).

5.5.2.3 Sensory Quality

Addition of cardamom significantly improved the flavour of kulfi mix

Table 54. Effect of incorporation of cardamom seed powder on microbiological quality of kulfi mix powder stored at 30° ± 1°C

Treatments	Storage period (months)	TVC x10^3	Staphylococcal count x10^2	Yeast and mould count x10
	Initial	18.1	8.3	7.1
	1	15.9	6.6	5.9
	2	13.7	5.9	5.1
	3	10.8	5.1	3.9
Control	4	8.3	4.3	3.1
	5	6.8	3.7	2.5
	6	4.7	1.9	1.1
	7	3.6	1.4	0.6
	8	2.8	0.9	0.4
	1	15.6	6.6	6.0
	2	13.5	5.4	5.1
	3	10.1	4.8	3.8
Cardamom	4	8.1	4.3	3.2
0.1 per cent	5	6.5	3.4	2.1
	6	4.2	1.4	0.9
	7	3.1	1.0	0.5
	8	2.6	0.7	0.2
	1	14.8	6.2	5.6
	2	13.1	5.0	4.8
	3	9.6	4.5	3.2
Cardamom	4	7.2	4.1	2.9
0.2 per cent	5	6.1	3.4	2.2
	6	3.9	1.2	0.7
	7	2.8	0.8	0.4
	8	2.3	0.6	0.1
	9	2.1	0.5	nil
	1	14.1	5.9	5.2
	2	12.5	4.3	4.1
	3	9.2	3.8	3.0
Cardamom	4	6.8	3.2	2.5
0.3 per cent	5	5.4	2.9	1.8
	6	3.2	1.0	0.5
	7	2.5	0.6	0.2
	8	1.4	0.4	0.1
	9	1.1	0.2	nil
	10	0.9	nil	nil

Note: Coliforms were absent, TDNase negative in all samples

powder during storage at 30° ± 1°C (Table 55). The flavour scores were found to increase with the increased amount of cardamom. This improvement was caused by decreased rate of fat oxidation or masking of oxidized/stale flavour by the aromatic compounds of cardamom. The minimum dose of 0.1 per cent did not improve the sensory scores as compared with the control samples. However, higher doses of 0.2 and 0.3 per cent enhanced the shelf-life of kulfi mix powder from flavour standpoint to nine and 10 months respectively. However, the product stored for 10 months became texturally defective. Formation of small lumps during storage made the product unacceptable after eight months of storage. The intensity of brown colour increased with the storage period as a result of browning reaction and caused reduction in colour scores.

It may be concluded that a combination of BHA and nitrogen gas is most effective in extending the shelf-life of tin packed kulfi mix powder to 10 months. Incorporation of cardamom improved the shelf-life only by one month upto eight months over that of control which could be preserved for seven months only.

5.6 LECITHINATION OF KULFI MIX POWDER

Lecithination of kulfi mix powder has been tried to give it better reconstitution properties than normal powder. Freshly prepared kulfi mix powder contains about 15.0 per cent free fat. This free fat floats on the surface of reconstituted kulfi mix giving it a defective appearance. This problem limits the acceptance of kulfi mix powder for instant use at homes. Lecithination process was, therefore, conceived as a possible approach to perfect reconstitution.

Table 55. Effect of incorporation of cardamom seed powder on sensory properties of kulfi mix powder stored at 30° ± 1°C

Treatments	Storage period (months)	Flavour	Body and texture	Colour and appearance
Control	Initial	8.0	8.0	8.0
	1	7.9	7.9	7.9
	2	7.8	7.8	7.8
	3	7.7	7.8	7.7
	4	7.5	7.6	7.5
	5	7.2	7.6	7.2
	6	6.8	7.4	6.9
	7	6.5	7.0	6.8
	8	6.3	6.7	6.6
Cardamom 0.1 per cent	1	7.9	7.9	7.9
	2	7.8	7.8	7.8
	3	7.7	7.7	7.7
	4	7.6	7.7	7.5
	5	7.4	7.6	7.3
	6	7.0	7.4	7.0
	7	6.8	7.0	6.8
	8	6.4	6.6	6.4
Cardamom 0.2 per cent	1	8.0	7.9	7.8
	2	8.0	7.8	7.7
	3	7.9	7.7	7.5
	4	7.8	7.6	7.5
	5	7.7	7.4	7.3
	6	7.5	7.3	6.8
	7	7.3	7.0	6.6
	8	7.0	6.6	6.5
	9	6.8	6.3	6.3
Cardamom 0.3 per cent	1	8.0	7.9	7.8
	2	8.0	7.8	7.7
	3	7.9	7.7	7.5
	4	7.9	7.5	7.4
	5	7.8	7.3	7.2
	6	7.7	7.2	6.9
	7	7.5	7.0	6.7
	8	7.2	6.5	6.5
	9	6.9	6.3	6.2
	10	6.6	6.1	6.0

5.6.1 PHYSICO-CHEMICAL CHARACTERISTICS

The physico-chemical characteristics of kulfi mix powder as influenced by the lecithination process have been presented in Table 56.

The moisture content of kulfi mix powder got decreased in lecithin treated samples because of secondary drying applied to powder (60°C for 45 min). Vilder (1987) also reported that lecithination of WMP decreased the moisture content.

Lecithination significantly reduced the bulk density of kulfi mix powder from 0.68 g/ml in control samples to 0.63 g/ml in treated samples. Similar observations were made by Vilder (1989) in WMP and it was due to greater agglomeration of lecithin coated powder particles.

The mean angle of repose was 58.10 for control and 58.70 for lecithinized kulfi mix powder. The reduction in flowability of powder due to lecithination could be attributed to increase in fat content (due to spraying of butteroil and lecithin mixture) on the surface of powder particles, which in turn increased the cohesiveness of powder particles (Pisceky, 1980). Lecithination was found to decrease the flowability of malted milk food (Salooja, 1983).

The wetting time of kulfi mix powder was significantly reduced by lecithination. The superior wettability of lecithin treated samples could be attributed to encapsulation of free fat with lecithin and slight agglomeration of particles (Tuohy, 1989). Lecithin is also known as a surface active agent.

There was no significant influence of lecithination on solubility index of kulfi mix powder. However, a slightly higher solubility index for lecithin treated samples could be due to additional heat treatment given

Table 56. Effect of lecithination on physico-chemical properties of kulfi mix powder

Characteristics	Control	Lecithin treated
Moisture (%)	2.53 ± 0.02	2.47 ± 0.04
Bulk density (g/ml)	0.68 ± 0.008	0.63 ± 0.007
Flowability (tan θ)	58.10 ± 0.21	58.70 ± 0.24
Wettability (sec)	30.20 ± 0.17	26.80 ± 0.19
Solubility index (ml)	1.20 ± 0.05	1.30 ± 0.03
Dispersibility (g)	28.96 ± 0.25	30.13 ± 0.18

Figures represent means of three replicates with SD

during secondary drying stage. Salooja (1983) also reported that solubility of malted milk food did not improve by lecithination.

Dispersibility of kulfi mix powder was slightly affected by lecithination since it is related to thermal history and not related to particle surface characteristics. Slightly higher dispersibility of lecithin treated kulfi mix powder might be due to agglomeration of particles.

It may be concluded that lecithination significantly improves the reconstitution properties of kulfi mix powder rendering it very suitable for instant use under household condition. However, before recommending this process for industrial production of lecithinized kulfi mix powder, further investigation on two- or three-stage drying system will be necessary to make use of lower drying temperature and to minimize the free fat content in the dried product.

5.7 MICROSTRUCTURE STUDIES

5.7.1 MICROSTRUCTURE OF KULFI MIX POWDER

The scanning electron microscopy of kulfi mix powder was done with a view to understand the correlation between the structure of particles and the physical and chemical properties. The surface and internal morphology may be useful in distinguishing kulfi mix powder from other milk powders.

Spray drying caused the formation of spherical particles of varying sizes. The particles of kulfi mix powder prepared with admixture of isabgol husk were also spherical in shape, but they showed a rough contour (Plate 4). Bhandari et al. (1984) observed that although the spray dried ice cream mix particles were spherical but each particle had a thick and viscid layer around. Such a change in the structure was attributed to the presence of pregelatinized potato starch which was used as stabilizer. The surface pits

and pores on kulfi powder particles are indicative of the occurrence of free fat (Plate 4). Free fat in spray dried powder particles may appear as patches or drops on surface (King, 1955) or in the form of small globules (Berlin et al., 1964). The surface pits were comparatively smaller in WMP (Plate 5) than those in kulfi mix powder. This could happen as a result of high free fat content in kulfi mix powder.

The bridges were observed between the particles of kulfi mix powder (Plate 6). These bridges could be formed by fat. Ranganadham (1988) also reported the presence of bridges in spray dried khoa powder. Fat bridges between WMP particles could influence the cohesiveness of milk powders (Buma, 1971a,b).

The cut surface of kulfi mix powder particles revealed the presence of one large single vacuole (Plate 7) with many small vacuoles. The WMP also exhibited almost similar internal structure (Plate 8). Buma and Henstra (1971b) also found the presence of a large vacuole in the centre of spray dried WMP particles. In the other experiments, two types of vacuoles, a large one occupying about half the particle volume and many tiny vacuoles were observed in SMP by Saito (1980) and in spray dried khoa powder by Ranganadham (1988). The feed liquid is accelerated inside the atomizer to high velocity during spray drying. Before the liquid leaves the atomizer, air bubbles of various sizes are dispersed into the liquid. Severe drying conditions contribute to large differences in velocity, vapour pressure and temperature between drying air and the droplets. Evaporation is very rapid as compared with the diffusion of water and solids inside the droplets. This causes large concentration gradients near the surface which promotes the development of a high viscosity surface layer and eventually forming a rigid crust (case hardening). Hence, more water will be present inside the droplet when the surface shrinks no more. The shrinkage associated with the evaporation of

Plate 4 Particle surface of kulfi mix powder - as observed under scanning electron microscope.

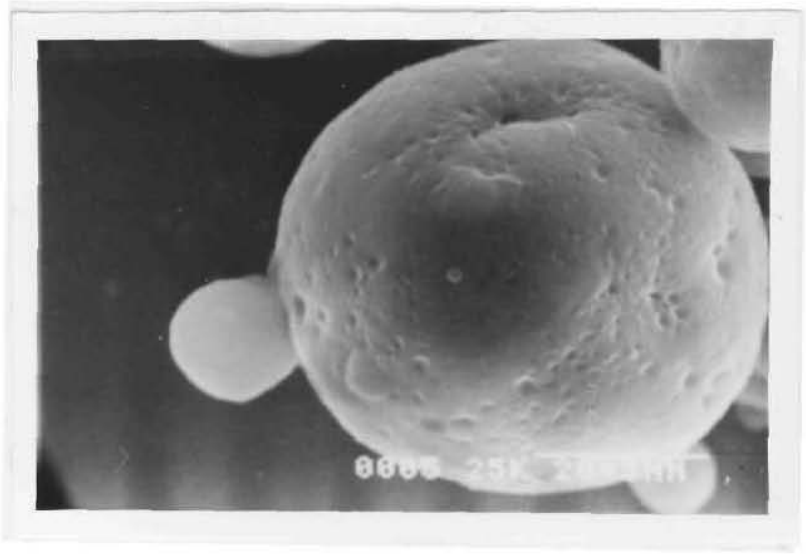
Magnification 1500 X

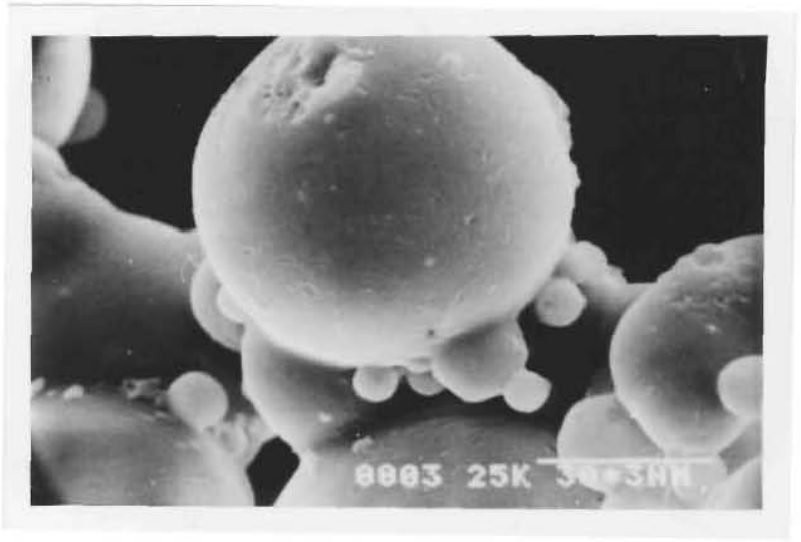
Plate 5 Particle surface of WMP - as observed under scanning electron microscope.

Magnification 1000 X

Plate 6 Fat bridges between particles of kulfi mix powder- as observed under scanning electron microscope.

Magnification 2000 X




0003 25K

25K 40

Plate 7 Internal structure of kulfi mix powder showing multiple vacuoles.

Magnification 1500 X

Plate 8 Internal structure of WMP showing single vacuole.

Magnification 1500 X

Plate 9 Scanning electron micrograph of ice crystals in kulfi without isabgol husk and stored for 2 hr at -12 ± 2°C.

Magnification 400 X

this larger volume of water will then force the air bubbles to expand and yield large vacuoles. Small air bubbles incorporated into the feed would leave numerous tiny vacuoles within the particles. The presence of large volume of vacuoles in kulfi mix powder samples might be the reason for the lower bulk density specially at higher drying temperature, viz., 190/92°C.

5.7.2 ICE CRYSTAL SIZE OF KULFI

The major role of stabilizers in frozen dairy products is to limit the size of ice crystals, to provide protection against heat shock and to promote dryness. Recent studies cast doubt on the ability of hydrocolloids to control size of crystals in frozen desserts. The present study was, therefore, conducted to know the influence of isabgol husk on formation and size of ice crystals. The morphology of kulfi samples at different stages of storage is shown in Plate Nos. 9 to 12. Plate 9 represents the typical photographs of samples having no stabilizer after 2 hr of storage at -12±2°C. The size of ice crystals represented by cavity size ranged from 25 to 45 u for the samples without stabilizer (Plate 9). However, the size of most of the ice crystals was found to range from 15 to 30 u for samples having 0.2 per cent isabgol husk (Plate 10). It is interesting to note that addition of isabgol husk helps in the formation of small ice crystals. After seven days of storage at -12 ± 2°C, the size of ice crystals increased to 75 to 105 u in samples without stabilizer (Plate 11) but in samples containing 0.2 per cent isabgol husk (Plate 12), the crystal size grew to 45 to 75 u. It would appear that many small ice crystals got fused together when the storage period was prolonged to one week.

From the above results, it could be ascertained that there was no marked influence of the stabilizer on size of ice crystals, but the size increased with prolonged storage. Kulfi samples prepared without stabilizer showed

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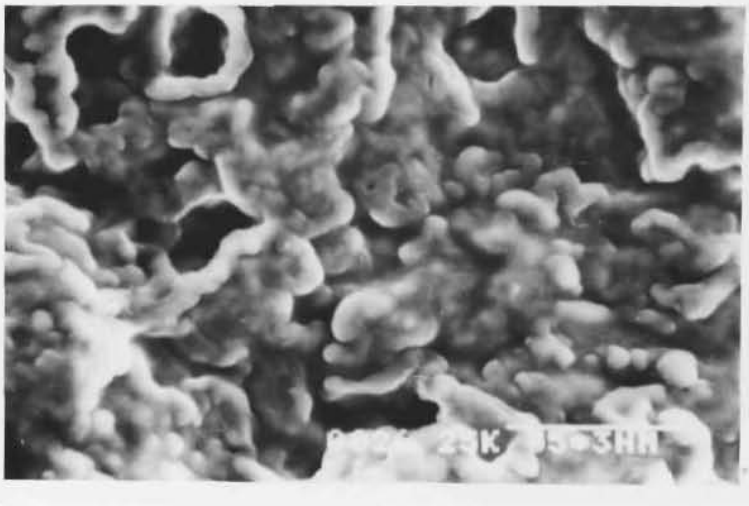


Plate 10 Scanning electron micrograph of ice crystals in kulfi with 0.2 per cent isabgol husk and stored for 2 hr at -12 ± 2°C.

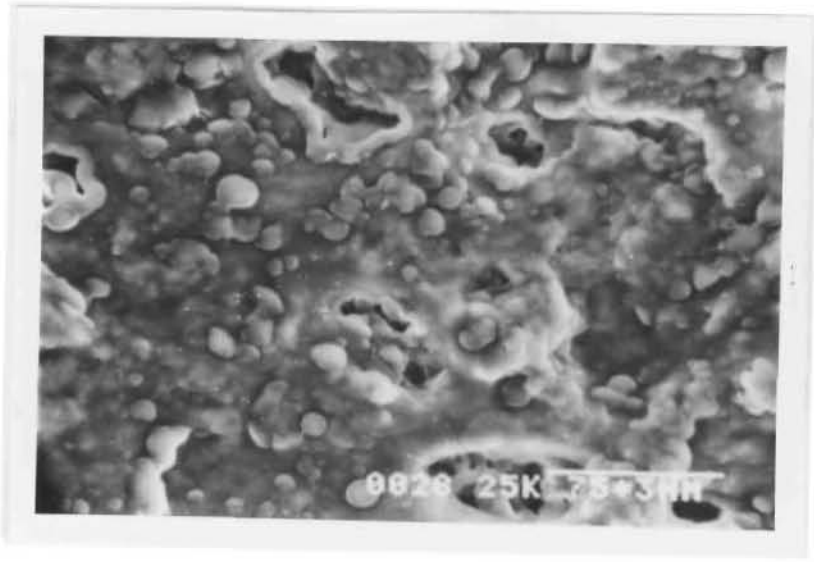
Magnification 400 X

Plate 11 Scanning electron micrograph of ice crystals in kulfi without isabgol husk and stored for seven days at -12 ± 2°C.

Magnification 400 X

Plate 12 Scanning electron micrograph of ice crystals in kulfi with 0.2 per cent isabgol husk and stored for seven days at -12 ± 2°C.

Magnification 400 X



maximum increase in crystal size during storage. It may be concluded that isabgol husk exerts only limited control over the size of ice crystals during storage. Similar observations were made by Moorthy (1990) in low fat ice cream containing isabgol husk, where the ice crystal size increased from 20.65 to 60.41 u after one week storage at -15 ± 2°C. Buyong and Fennema (1988) also observed that a number of polysaccharide hydrocolloids, used as ice cream stabilizers, exert only minimal control over ice crystal growth in ice cream. Hydrocolloids were not found to decrease the amount of ice formed in dessert ices as reported by Muhr et al. (1986).

5.8 COST OF KULFI MIX POWDER PRODUCTION

The economic viability and technological feasibility of any product are the two important considerations for successful marketability. Entrepreneurs would like to know the total costs involved in establishing a spray drying unit for kulfi mix powder. The cost of production was estimated with the help of current cost data available in the Experimental Dairy of the Institute which has got a milk processing capacity of 10,000 litres per day.

The cost model developed for kulfi mix powder is depicted in Table 57. A spray drying unit capable of producing two metric tons of powder per day is conceptualized as a model for calculating the cost. It is presumed that the plant would operate for 20 h a day and 300 days in a year. The capacity of spray drier will be 150 kg of water evaporation/hr. The outturn of the product from the mix containing 40.0 per cent TS would be 110 kg/hr x 20 hr a day x 300 days or 6,60,000 kg powder/year. After dry blending of sugar with powder in the ratio of 35.5:100 (as described in section 5.3), the finished product quantity will be 8,94,300 kg/year. Considering 3.0 per cent handling and stack losses, the theoretical product outturn woule be 8,67,471 kg/year.

The cost of production of kulfi mix powder was worked out to Rs.38/kg.

Table 57. Cost of production of kulfi mix powder

1.	**Inputs**	
	Buffalo milk @ 12,250.00 kg/day (6.5 fat and 9.0 per cent SNF) for manufacturing 2,980 kg kulfi mix powder	36,75,000 kg/annum
		Rs.
2.	**Fixed cost**	
	A. Land 1,000 sq m @ Rs.150/sq m	1,50,000
	B. Building 300 sq m @ Rs.2,150 sq m	6,45,000
	C. Equipments:	
	1. Raw milk reception (3,000 kg/hr)	1,00,000
	2. Refrigeration plant (5 tonnes)	3,50,000
	3. Storage tank (15,000 kg) 1 No.	2,60,000
	4. Cream separator (1,000 kg/hr) 1 No.	1,10,000
	5. Tubular heat exchanger (300 kg/hr) 1 No.	50,000
	6. Multiple effect evaporator (500 kg water evaporator/hr)	6,50,000
	7. Spray drier (150 kg water evaporation /hr)	15,00,000
	8. Homogenizer (500 kg/hr)	3,00,000
	9. Vacuum chamber for tin cans 1 No.	50,000
	10. Steam boiler (1,000 kg steam/hr)	3,00,000
	11. Ghee boiler (200 kg) 1 No.	1,00,000
	12. Tin seamer for kulfi powder 1 No.	50,000
	13. Plastic sealing impulse heater for ghee 1 No.	25,000
	Total equipment cost	38,45,000
	Total fixed cost (A+B+C)	46,40,000
3.	**Variable cost**	
	3.1 Raw materials and utilities:	
	a) Milk @ Rs.5.00/kg (36,75,000 kg/annum)	1,83,75,000
	b) Refined sugar @ Rs.9.00/kg (3,09,900 kg/annum)	27,89,100

contd.....

contd..... table 57

			Rs.
	c) Isabgol husk @ Rs.100.00/kg (4,200 kg/annum)		4,20,000
	d) Nitrogen gas cylinder @ Rs.300.00/cylinder (660 cylinders/annum)		1,98,000
	e) Packaging material (tin cans) 1 kg capacity @ Rs.8.00/tin can		69,56,163
	f) Packaging material (for ghee) High density polyethylene pouch double liner @ Rs.2.00/pouch		22,800
	g) Water		3,15,350
	h) Steam		20,89,188
	i) Refrigeration		44,044
	j) Electricity		3,15,350
	3.2 Labour and supervision:		
	a) Production Manager @ Rs.4000/month	1 No.	48,000
	b) Shift Manager @ Rs.3000/month	3 Nos.	1,08,000
	c) Quality Control Manager @ Rs.3000/month	1 No.	36,000
	d) Plant Operators @ Rs.2000/month	6 Nos.	1,44,000
	e) Laboratory Technician @ Rs.2000/month	2 Nos.	48,000
	f) Unskilled labour @ Rs.32/day	12 Nos.	1,40,160
	3.3 Other costs:		
	a) Chemical, glassware		50,000
	b) Office contingency		50,000
	Total variable cost		3,21,49,155
4.	Depreciation on machinery and building (@ 2.5 per cent for building cost and 10.0 per cent for machinery)		4,00,625
5.	Interest on fixed capital and working capital for one months @ 18.0 per cent		13,17,437
6.	Total expenditure (variable cost + depreciation + interest)		3,38,67,217

contd.....

contd.... table 57

7.	Output	
	a) Kulfi mix powder	8,52,471 kg/annum
	b) Income from sale of 11,400 kg ghee @ Rs.75/kg	Rs. 8,55,000
	c) Income from sale of 15,000 kg chamber sweepings @ Rs.20/kg	Rs. 3,00,000
8.	Net cost of production of 8,52,471 kg kulfi mix powder [6-(7b+7c)]	Rs.3,27,12,217
	Cost of one kg of spray dried kulfi mix powder (tin packed)	Rs.38.37
	or say	Rs.38/kg

Note: One kg of kulfi mix powder is mixed with 1.3 kg water to yield 2.3 kg reconstituted kulfi mix. Adding another 30 per cent of price of dried kulfi mix as reconstitution, freezing and packaging cost towards kulfi making, it comes about Rs.49 per 2.3 kg mix.

Therefore, cost of one cone (100 g) of kulfi (considering 3.0 per cent handling loss) $= \frac{49}{22}$

= Rs.2.23

or say Rs.2.25

The raw materials, processing and packaging costs were calculated as 66, 12 and 22 per cent respectively. The packaging cost for kulfi mix powder was higher than that reported by Ranganadham (1988) for khoa powder (spray process) in the years 1987-1988. According to him, the raw material, processing and packaging costs respectively took 80.29, 13.75 and 5.96 per cent share of the total cost of production. The prices of all the commodities, especially the costs of packages and energy have escalated during the recent weeks. The lower cost of processing of kulfi powder is partly achieved by dry blending of sugar with powder. It may be pointed out that the cost of kulfi mix powder would further decrease with increased size of operation. The spray drying technology for kulfi powder is economically viable and technologically feasible under the set-up reported here.

5.9 TEST MARKETABILITY

The marketing potential and consumers' response to kulfi prepared from kulfi mix powder were assessed by offering the product for sale at the Institute Milk Parlour. The price per cone of kulfi (100 g) was fixed at Rs.3/- only. The consumers were supplied with a product rating card (Annexure III). There was an overwhelming response for the product at the sales counter and the consumers' reactions have been summarised in Table 58.

Table 58. Consumers' response for kulfi prepared from kulfi mix powder

Quality grading	No. of consumers	Percentage
Excellent	28	18.66
Very good	73	48.67
Good	31	20.67
Fair	15	10.00
Poor	3	2.00
Total	150	100.00

It can be inferred that most consumers found the product acceptable from the standpoint of quality and cost. The consumers were ready to purchase the product frequently since they found it very economical and delicious. Two per cent of the consumers who rated the product as poor belonged to the group which suggested the incorporation of dry fruits and nuts to kulfi. Manufacturers may add fruits and nuts to kulfi but the price will have to be raised.

CHAPTER 6

SUMMARY

6. SUMMARY

Kulfi is a very popular traditional frozen milk product of Indian origin. Ironically, no standard method for its industrial production has so far been developed. Halwais, who have learnt the art of kulfi making, do not wish to divulge the knowledge to others because of the inherent fear of competition. The unhygienic conditions prevailing at the kulfi making centres and apathy of the traders for adopting scientific and sanitary practices lead to public health hazards. Scarcity of published data on the chemical, microbiological and sensory attributes and paucity of information on mechanized production methods discourage the organized dairy sector to start the industrial production of kulfi.

The present investigation was planned with a view to establish consumers' preference for quality attributes of kulfi so that the optimum product formulation and processing conditions could be standardized. The production of instant kulfi mix powder using spray drying technology was conceived as a profitable proposition for dairy plants possessing condensing and drying facilities. Availablility of technology for the manufacture of instant kulfi mix will enable dairy food factories to plan the production of a revenue generating product. The technology so developed will also help in profitable utilization of regional and seasonal surpluses of milk. The product packed in a protective packaging material with a reasonable shelf life will have a high demand at the city kulfi manufacturing centres and at homes for instant use.

The studies on market quality of kulfi sold in Karnal and Delhi markets showed large variations in the chemical, microbiological and sensory properties.

The mean TS values of 39.04 and 44.54 per cent in samples of kulfi collected from Karnal and Delhi markets were accompanied with large variations in fat (6.56 to 11.65 per cent in Karnal and 10.07 to 13.87 per cent in Delhi samples) and sucrose (13.92 to 17.92 in Karnal and 14.37 to 20.46 in Delhi). Distinct variations were also observed in protein, lactose, ash, and physico-chemical properties like titratable acidity, relative viscosity, surface tension and melt down quality.

Most of the market samples of kulfi were heavily contaminated with the different types of micro-organisms. The average microbial counts in kulfi samples per g for Karnal and Delhi markets were: TVC 17.15×10^5 and 15.52×10^5; coliforms 61.73×10^2 and 6.20×10^2; staphylococci 26.32×10^5 and 8.46×10^5; and yeast and mould 6.14×10^2 and 2.11×10^2 respectively. The microbiological quality of Delhi samples of kulfi was better than that of Karnal samples. About 20 per cent of the kulfi samples of Karnal and 10 per cent of Delhi were found to contain staphylococcal TDNase which poses great risk to public health.

The sensory quality of most preferred samples of kulfi was described by slightly cooked or caramelized flavour, creamy taste, fine grainy texture and slight brown colour. Presence of large sized ice crystals cogulated milk particles and fast melt down diminished the product acceptability.

Kulfi is either sold on an individual cone basis or at times on weight basis from a large vessel. The net weight of market samples of kulfi in cones varied from 95.0 to 107.0 g. The retail price per cone of kulfi during the year 1989-90 ranged from Rs.4.50 to 6.00 and Rs.6.00 to 7.00 for Karnal and Delhi markets respectively.

A method was developed for industrial production of kulfi. The ideal composition of kulfi mix was figured out with: fat 11.0 per cent, MSNF 16.0 per cent, sugar 15.0 per cent and isabgol 0.20 per cent.

The optimum processing of kulfi mix required: homogenization at 6.86/3.43 MPa, heating at 100°C for 10 min in a tubular heat exchanger, cooling to 4°C, flavouring, filling in moulds, freezing in brine tank followed by hardening and storage at -23° to -25°C. The physico-chemical properties of kulfi mix with the composition mentioned above were: (mean values) acidity 0.28 per cent LA, pH 6.37, specific gravity 1.1230, relative viscosity 2.41, surface tension 49.25 dynes/cm, and melt down of kulfi 24.0 ml in 30 min at 30°C.

The manufacture of kulfi mix powder by spray drying technique was standardized for commercial exploitation. The standardized technology involved the adjustment of TS of the mix to 40.0 per cent (containing 4.84 per cent sugar), two-stage homogenization of mix at 6.86/3.43 MPa pressure at 70-75°C, heat treatment in a tubular heat exchanger at 100°C for 10 min, spray drying at an inlet air temperature of 180°C and the outlet air temperature of 85°C, adjusting the atomizer speed at 20,000 rpm, dry blending of remaining amount of refined sugar with powder in the ratio of 35.5:100 (weight basis), packaging and storage.

The mean chemical composition of kulfi mix powder was: moisture 2.52, fat 25.41, protein 14.56, lactose 19.43, sugar 34.65, ash 2.97 and isabgol 0.46 per cent. The bulk density and free fat content of kulfi mix powder were 0.68 g/ml and 15.65 per cent respectively. The product had moderately cooked flavour, fine texture and slightly brown colour.

The suitability of metallized polyester and tin cans for packaging of kulfi mix powder for storage at 30°C was studied. The shelf-life of the product packed in tin and metallized polyester was seven and six months respectively. The type of package and storage period showed significant influence on the survival of microorganisms in kulfi mix powder. The initial

TVC of 18.5 x 10^3 in kulfi powder got decreased to 4.1 x 10^3 in six months when packed in metallized polyester and to 2.6 x 10^3 after eight months storage in tin containers. All the samples of kulfi mix powder were free from coliform and staphylococcal TDNase.

The type of packaging material and storage period of kulfi powder significantly affected the physico-chemical properties of reconstituted kulfi mix. However, the rate of change of these properties was faster in samples packed in metallized polyester. Titratable acidity of reconstituted kulfi mix increased and pH decreased with advancing storage period. Viscosity, surface tension and melting resistance of kulfi also decreased with progressive storage.

Use of 0.01 per cent BHA by weight of powder and nitrogen gas flushing were effective in slowing down the oxidative deterioration of fat in kulfi powder. The shelf-life of the product treated with BHA or gas flushed was extended to eight months at 30°C in tin containers. However, a combination of BHA and nitrogen gas proved to be most effective in extending the shelf-life upto 10 months. Incorporation of cardamom (0.2 per cent w/w) improved the shelf-life by an additional one month upto eight months over that of control which could be preserved for seven months at 30°C.

Lecithination improved the reconstitution properties of kulfi mix powder rendering it highly suitable for instant use in household conditions.

The scanning electron microscopy revealed that spray dried kulfi mix carried spherical particles of different sizes. The surface pits indicative of free fat were present in abundance in kulfi mix powder but much less in number in WMP particles. The internal structures (cut particles) of kulfi mix powder and WMP were almost identical with same entities carrying a large central vacuole and others having numerous smaller vacuoles.

The size of ice crystals in kulfi increased during deep freezing. This

increase was more pronounced in samples prepared without stabilizer. Size of the ice crystals in samples containing 0.2 per cent isabgol husk was 15 to 30 u but after seven days storage at -12 ± 2°C it increased to 45 to 75 u. Isabgol husk could exert only limited control on the size of ice crystals during storage.

The cost of production of kulfi mix powder worked out to Rs.38 per kg. The costs shared by raw material, processing and packaging were calculated as 66, 12 and 22 per cent respectively in the total cost of production.

The marketing potential and consumer acceptance of kulfi prepared from kulfi mix powder was evaluated by offering the frozen product for sale at the Institute Milk Parlour. About 88 per cent of a total of 150 consumers rated the kulfi as excellent or good and 10 per cent found it of fair quality.

ABSTRACT

Kulfi (Indian ice cream) is a very popular traditional frozen milk product of Indian origin. The market quality of most preferred samples of kulfi collected from Karnal and Delhi revealed wide variations in total solids (33.95 to 49.13 per cent), fat (6.56 to 13.87 per cent) and sucrose (13.87 to 20.46 per cent). Market samples were heavily contaminated with staphylococci and coliform bacteria indicating improper hygienic practices followed during the manufacture and distribution. Kulfi samples having slightly cooked or caramelized flavour, creamy taste, uniform fine grainy texture and slight brown colour were liked most by the panelists. Presence of large sized ice crystals and coagulated milk particles reduced the product acceptability. The technology was standardized for industrial production of kulfi with quality attributes conforming to legal standard. The most preferred mix was formulated from milk fat 11.0 per cent, MSNF 16.0 per cent, sucrose 15.0 per cent and isabgol husk 0.2 per cent. The mix was homogenized at 6.86/3.43 MPa, heat treated at 100°C for 10 min in a tubular heat exchanger, cooled to 4°C, filled in moulds and frozen at -20°C in a brine tank with continuous shaking until the product got frozen. The formulation for spray drying of kulfi mix was modified to contain 25.0 per cent of the total sucrose required in the final mix. The processing conditions for spray drying were: inlet temperature 180°C and outlet temperature 85°C, atomizer speed 20,000 rpm and mix concentration 40.0 per cent (containing 4.84 per cent sucrose). The remaining balance of ground sucrose was dry blended with powder in the ratio of 35.5:100 (w/w) followed by packaging and storage. The proximate chemical composition of kulfi mix powder was: fat 25.41, MSNF 36.96, isabgol 0.46, sugar 34.65 and moisture 2.52 per cent. The product had a shelf-life of seven months at 30°C in tin can, extendable to eight months with the addition of BHA (0.01 per cent) and to 10 months with the combination of BHA and nitrogen gas flushing. The reconstituted kulfi samples were comparable in sensory properties with those of the control samples prepared in the traditional manner. The cost of production of kulfi mix powder worked out to Rs.38 per kg. Ultrastructure studies were also conducted to elucidate the morphology of particles of kulfi powder and kulfi.

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ANNEXURES

ANNEXURE I

KULFI SCORE CARD

Please write scores opposite the rating for perfect score. Check criticisms and tick mark the defect in the space provided for each sample.

Desirable attributes of kulfi

Kulfi should have a pleasant aroma and cooked flavour, creamy taste and uniform consistency, free from big sized ice crystals and coagulated milk particles. A slight brown colour is not a defect.

Perfect score	Criticism	Sample number 1	2	3	4	5
FLAVOUR : 50 Normal range 35-45	Judge's score					
	Burnt					
	Stale					
	Neutralizer					
	Oxidized					
	Rancid					
	Too sweet					
	Unclean/Putrid					
	Unnatural					
BODY AND TEXTURE : 35 Normal range 25-30	Judge's score					
	Weak					
	Coarse/Icy					
	Hard					
	Brittle					
	Lack of grains					
	Sandy/Gritty					
	Soggy/Gummy					
	Sticky/Pasty					
COLOUR AND APPEARANCE:10 Normal range 6-8	Judge's score					
	Dull white					
	Brown					
	Uneven/Mottled					
	Unnatural					
MELTING QUALITY : 5 Normal range 4-5	Judge's score					
	Foamy					
	Oiling off					
	Fast melting					
	Slow melting					

Name: Date:

Comments: Signature:

ANNEXURE II

SENSORY EVALUATION CARD

(HEDONIC RATING TEST)

Batch No. _____ Date of manufacture _____

A. Name _____ Date _____

B. Product Kulfi mix powder _____ Time _____

C. Please rate the samples for quality attributes according to the 9-point Hedonic scale given below:

1.	Liked extremely	9
2.	Liked very much	8
3.	Liked moderately	7
4.	Liked slightly	6
5.	Neither liked nor disliked	5
6.	Disliked slightly	4
7.	Disliked moderately	3
8.	Disliked very much	2
9.	Disliked extremely	1

Characteristics	Sample number				
	1	2	3	4	5
Flavour					
Body and texture					
Colour and appearance					

D. Remarks, if any

Sample No. 1 _____

2 _____

3 _____

4 _____

5 _____

Signature

ANNEXURE III

PRODUCT RATING CARD

(CONSUMER SURVEY)

Product Kulfi _____ Price _____

Name _____ Age _____

Sex _____ Occupation _____

I. Please indicate your preference for the product by placing a tick mark ( ) against any one of the following grades:

GRADE	
Excellent	_____
Very good	_____
Good	_____
Fair	_____
Poor	_____

II. Do you think the price of the product is

Too high	_____
Optimum	_____
Too low	_____ .

III. How often would you like to buy this product?

IV. Any other comments.

64921
24/8/92

Date _____ Signature _____