OUTLINES OF DAIRY TECHNOLOGY

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This book is dedicated to
my wife Shailaja,
without whose encouragement,
inspiration and moral support,
it would never have been
written.

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FOREWORD

A competent teacher of dairy technology who has had a succession of undergraduates to handle, is bound to know how to present the 'basics' and 'essentials' of his subject to students of varying calibre and receptivity. As a research worker, who also guides students doing postgraduate work, he has to remain in close touch with recent advances made in his field. Professor Sukumar De, the author of this work, is such a person and is, in addition, a proven pioneer in his field who has contributed to our knowledge of the peculiarities and problems which dairying in India presents. Given this background, his special qualifications to write a textbook on dairy technology cannot be in doubt.

Ever since I first met him in 1946 as an esteemed colleague, Professor Sukumar De has been both a teacher and a researcher. This, together with his membership for more than three decades of the staff of an institution of unquestionable pre-eminence—the National Dairy Research Institute, Karnal—has provided Professor De with a rich background for writing this book.

A perusal of *Outlines of Dairy Technology* amply fulfils the specialist's expectations. Its treatment of the subject-matter of each chapter, and its special attention to the Indian context, is in the best traditions of scholarship. In its five hundred odd pages, divided into twelve chapters and five appendices, every aspect of dairy technology conforming to the approved diploma/degree syllabus has been discussed with skill and in a manner at once succinct and economic in expression. The sequence of treatment is well thought-out and appropriate.

The impetus given to the development of dairying in India, especially during the last quarter of a century, encouraging enquiries, information and research, has also found a place in the book, in sufficient detail to contribute to the knowledge of students/fellow professionals, while at the same time arousing their interest and curiosity to read beyond it.

I feel certain that the book will be keenly sought after not only by students of dairying in India (and other developing countries) but also by teachers, researchers, plant managers and extension workers who need a dependable reference book at hand.

S C. RAY

PREFACE

The Indian Dairy Industry has made rapid progress since Independence. A large number of modern milk plants and product factories have since been established. These organized dairies have been successfully engaged in the routine commercial production of pasteurized bottled milk and various Western and Indian dairy products. Most of the supervisory and technical personnel in these dairies have had their dairy education in this country, although a few have been trained abroad as well. The author has had the privilege of sharing his knowledge of dairy technology with many of these persons during the past two or three decades. Lately there has been a persistent demand from these and other sources that I write a book on Dairy Technology for the benefit of students and industry alike.

Although standard books dealing with dairy products have been published in the West, their expense and non-availability on easy terms makes it rather difficult for Indian students to procure them. It was, therefore, considered desirable to compile in one volume the salient aspects of the processing and manufacture of various types of milks and milk products. This book has been written in clear and concise language, the text-matter supplemented with tables, illustrative problems and their solutions, and photographs of some of the equipment used in the dairy industry. Moreover, enough current scientific information has been included in it to justify its publication. A chapter on Indian Dairy Products is a special feature. I am sure it will not only serve as a textbook on Dairy Technology for Indian students but also as a reference book for our dairy factory supervisors.

The book has been divided into twelve chapters, viz., Market Milk, Special Milks, Cream, Butter, Butteroil, Ice Cream, Cheese, Condensed Milks, Dried Milks, Dried Milk Products, Indian Dairy Products and dairy By-products. At the end, there are five appendices and a list of books recommended for further reading.

I am indebted to the authors, editors and publishers of various scientific books, periodicals and pamphlets from which most of the information presented here has been gathered. In particular, I have freely consulted the following:

1. *Market Milk* by H. H. Sommer
2. *The Butter Maker's Manual* by F. H. McDowall
3. *Ice Cream* by W. S. Arbuckle
4. *Cheese* by J. G. Davis
5. *Condensed Milk and Milk Powder* by O. F. Hunziker
6. *Drying of Milk and Milk Products* by C. W. Hall and T. I. Hedrick
7. *By-Products from Milk* by B. H. Webb and E. O. Whittier
8. *Judging Dairy Products* by J. A. Nelson and G. M. Trout
9. *Indian Dairy Products* by K. S. Rangappa and K. T. Achaya
10. *Milk Products of India* by M. R. Srinivasan and C. P. Anantakrishnan
11. *Indian Dairyman* and *Indian Journal of Dairy Science*
12. *Indian Standards*

I am indeed grateful to Sri Mohindra Singh Saini, stenographer in Dairy Technology Division, N.D.R.I., Karnal, for typing the manuscript diligently and accurately. Thanks are due to all my students (past and present), friends and well-wishers for their continued support in this endeavour.

I would like to express my deep gratitude to Dr S. C. Ray, President, Indian Dairy Association, for not only writing the Foreword, but also for offering invaluable suggestions regarding the text. I am highly indebted to Dr D. Sundaresan, Director, N.D. R.I., Karnal, for issuing me a letter of recommendation. I record my grateful thanks to the National Book Trust, India, for their generous financial assistance which has made the book easily accessible to students. Lastly, to Oxford University Press, New Delhi, to whom I am most indebted, since without their kind co-operation this book would not have seen the light of day.

September 1977 SUKUMAR DE

GENERAL INTRODUCTION

A dairy is a place for handling milk and milk products. Technology refers to the application of scientific knowledge for practical purposes. Dairy technology has been defined as that branch of dairy science which deals with the processing of milk and the manufacture of milk products on an industrial scale. In developed dairying countries such as the U.S.A., the year 1850 is seen as the dividing line between farm and factory-scale production. Various factors contributed to this change in these countries, viz. concentration of population in cities where jobs were plentiful, rapid industrialization, improvement of transportation facilities, development of machines, etc. Whereas the rural areas were identified for milk production, the urban centres were selected for the location of milk processing plants and product manufacturing factories. These plants and factories were rapidly expanded and modernized with improved machinery and equipment to secure the various advantages of large-scale production. This heralded the advent of dairy technology in these countries.

In India, dairying has been practised as a rural cottage industry since the remote past. Semi-commercial dairying started with the establishment of military dairy farms and co-operative milk unions throughout the country towards the end of the nineteenth century. However, market milk technology may be considered to have commenced in 1950, with the functioning of the Central Dairy of Aarey Milk Colony, and milk product technology in 1956 with the establishment of AMUL Dairy, Anand.

In this book, *Outlines of Dairy Technology*, the main principles of the production of various types of milks and milk products, both Western and Indian, have been discussed in sufficient detail to meet normal requirements. A few books, some of a general nature, and others dealing with specific products, have been recommended for supplementary information.

OUTLINES OF DAIRY TECHNOLOGY

1 MARKET MILK

1.1 Introduction

As a major enterprise, the market milk industry is of comparatively recent origin even in developed dairying countries (such as the U.S.A.). Though ancient written records report milk as an important food, its processing and distribution as a separate commercial business did not develop in those countries until the concentration of population in the cities reached a high level in the middle of the nineteenth century.

During the earlier years, each household in those countries maintained its 'family cow' or secured milk from its neighbour who supplied those living close by. As the urban population increased, fewer households could keep a cow for private use. The high cost of milk production, problems of sanitation (which led to sanitary regulations by Public Health Authorities), etc., restricted the practice; and gradually the family cow in the city was eliminated and city cattle were all sent back to the rural areas.

Gradually farmers within easy driving distance began delivering milk over regular routes in the cities. This was the beginning of the fluid milk-sheds which surround the large cities of today. Prior to the 1850s most milk was necessarily produced within a short distance of the place of consumption because of lack of suitable means of transportation and refrigeration.

With modern knowledge of the protection of milk during transportation, it became possible to locate dairies where land was less expensive and crops could be grown more economically. The milk supply of the large cities of the U.S.A. now comes largely from 80–160 kms or more away.

Nearly all the milk in the U.S.A. before 1900 was delivered as raw (natural) milk. Once pasteurization was introduced, it caught on rapidly. Mechanical refrigeration contributed to the rapid development of the factory system of market milk distribution.

In India, the market milk industry may be said to have started in 1950–1 when the Central Dairy of Aarey Milk Colony was commissioned and went into stream. The industry is still in its infancy and barely 10 per cent of our total milk production undergoes organized handling.

1.2 Definition

The term 'market milk' refers to fluid whole milk that is sold to individuals usually for direct consumption. It excludes milk consumed on the farm and that used for the manufacture of dairy products.

Note. Milk may be defined as the whole, fresh, clean, lacteal secretion obtained by the complete milking of one or more healthy milch animals, excluding that obtained within 15 days before or 5 days after calving or such periods as may be necessary to render the milk practically colostrum-free, and containing the minimum prescribed percentages of milk fat and milk-solids-not-fat. In India, the term 'milk', when unqualified, refers to cow or buffalo milk, or a combination of the two. (Also see 1.4.)

1.3 The Market Milk Industry in India and Abroad

(a) Although a beginning in organized milk handling was made in India with the establishment of Military Dairy Farms (oldest: Allahabad, 1889), the salient features of the market milk industry so far have been:

(i) Handling of milk in Co-operative Milk Unions (oldest: Allahabad, 1913) established all over the country on a small scale in the early stages.

(ii) Long distance refrigerated rail-transport of milk from Anand to Bombay since 1945.

(iii) Pasteurization and bottling of milk on a large scale for organized distribution was started at Aarey (1950), Worli (1961), Calcutta (Haringhata, 1959), Delhi (1959), Madras (1963), etc.

(iv) Establishment of Milk Plants under the Five-Year Plans for Dairy Development all over India. These were taken up with the dual object of increasing the national level of milk consumption and ensuring better returns to the primary milk producer. Their main aim was to produce more, better and cheaper milk. The actual expenditure is given in Table 1.1.

TABLE 1.1

Actual expenditure on the market milk industry in India's Five-Year Plans

Plan Period		Expenditure
I Five-Year Plan	(1951–6)	Rs 7.8 crores
II -do-	(1956–61)	Rs 12.0 crores
III -do-	(1961–6)	Rs 36.6 crores
Spill-over I to III	(1966–7)	Rs 25.7 crores

SOURCE: *Dairying in India* by Khurody (1974).

(b) The present status of the market milk industry in this country may be gauged from the following facts and figures:

(i) Total annual milk production in India has been estimated at 25 million tonnes (1976).

(ii) Although India possesses nearly one-fifth of the world's bovine population (cow, buffalo and goat), milk production in India accounts for only about one-sixteenth of the world's total of 428 million tonnes (1975).

(iii) Due to the large human population, daily per capita milk consumption today (1975) works out to about 114 g, while that recommended by the Medical Authorities is 280 g.

(iv) The main reasons for this acute shortage of milk are low milk-yielding capacity of the average Indian cow and acute shortage of feeds and fodder.

(v) Lack of organized milk production and collection, restricted transport facilities (especially refrigerated) and shortage of processing and marketing organizations have greatly hampered the growth of the market milk industry.

(vi) Poor-quality milk, widespread adulteration, and lack of quality consciousness among the great majority of consumers have further aggravated the situation.

(c) Table 1.2 gives India's position in relation to some of the important milk producing countries of the world:

TABLE 1.2

India's position in relation to milk producing countries of the world

Country	Animals in milk (millions)	Milk yield/ milking cow/ annum (kg)	Total milk production* (1000 × tonnes)
U.S.S.R.	41.2	2200	82,900
U.S.A.	14.1	4154	52,800
France	8.7	3130	30,413
India	53.0	B—450 C—157	21,360
W. Germany	5.9	3779	22,545
Poland	6.2	2361	14,860
U.K.	5.3	3950	13,000

*Cows, buffaloes, goats and sheep.

SOURCE: *F.A.O. Production Year Book*, 1970.

(d) The production of milk in India for selected years is given n Table 1.3.

TABLE 1.3

Milk production in India

Year	Production (Million tonnes)
1951–2	17.5
1956–7	19.7
1961–2	20.4
1968–9	21.2
1973–4	23.2
1978–9	28.6 (estimate)

SOURCE: *Dairying in India*, IDSA Publication, 1976.

(e) The proportion of cow, buffalo and goat milks to total milk production in India is given in Table 1.4.

(f) The density of milk production (i.e., daily milk production) for India is given in Table 1.5.

(g) A summary showing the utilization of 19.4 million tonnes of milk in India (1966) is given in Table 1.6.

TABLE 1.4

Species contribution to total milk production in India

Type of Milk	Total production	
	Per cent	Amt (1000 × tonnes)
Cow	33.6	8,400
Buffalo	63.6	15,900
Goat	2.8	681

SOURCE: *F.A.O. Production Year Book*, 1974.

TABLE 1.5

Density of milk production in India

Category	Per village	State	Per sq. km
Min.	11 kg	Assam	2.1 kg
Ave.	88 kg	Indian Union	15.6 kg
Max.	472 kg	Delhi	98.0 kg

Note. District Amritsar 113.3 kg/sq. km
Denmark 362.1 kg/sq. km

SOURCE: *Report of the Marketing of Milk in the Indian Union* (1961).

TABLE 1.6

Summary of utilization of milk in India

Items	Percentage in relation to	
	Total milk production	Total quantity converted into milk products
Fluid milk	44.5	—
Manufactured milk	55.5	(100)
Ghee	32.7	58.9
Dahi	7.8	14.0
Butter	6.3	11.4
Khoa	4.9	8.8
Ice cream	0.7	1.3
Cream	1.9	3.4
Other products (Mainly chhana)	1.2	2.2

SOURCE: *Indian Dairyman* (1976), **28** (11), 512.

(h) The daily per capita consumption of milk in some of the major developed dairying countries (1970) is given in Table 1.7, and that in developing countries in Table 1·8.

TABLE 1.7

Daily per capita milk consumption in some developed countries of the world (1970)

Country	Estimated daily per capita consumption in terms of liquid milk (g)	Country	Estimated daily per capita consumption in terms of liquid milk (g)
U.K.	1315	France	1335
Australia	1144	W. Germany	1301
New Zealand	2032	Netherlands	1121
Canada	1158	Norway	2046
U.S.A.	1003	Sweden	1812
Denmark	1188	Switzerland	1588
Finland	2165		

SOURCE: Miscellaneous.

TABLE 1.8

Daily per capita milk consumption in some developing countries of the world (1975)

Country	Estimated daily per capita consumption in terms of liquid milk (g)	Country	Estimated daily per capita consumption in terms of liquid milk (g)
Bangladesh	51	Israel	577
India	114	Japan*	122
Iran	172	Pakistan	225
Iraq	170	Philippines	2

*Now considered a developed country.

SOURCE: *Indian Dairyman*, **29** (3), 150 (1977).

Note. The market milk industry in the advanced dairying countries of the world has now reached a high level in sanitary production, transportation, processing and distribution. These improved conditions are a result of the passage of dairy and milk-control ordinances in nearly all major cities, and of control laws in states where dairying is important. Credit should also be given to many producers, distributors and manufacturers of dairy equipment for setting high standards.

1.4 Indian Standards

According to the Prevention of Food Adulteration (PFA) Rules, 1976, the standards for different classes and designations of milk in India should be as given in Table 1.9.

TABLE 1.9

Standards of different milks in India

Class of milk	Designation	Locality	Minimum	
			% MF*	% MSNF†
Buffalo milk	Raw, pasteurized, boiled, flavoured and sterilized	Assam; Bihar; Chandigarh; Delhi; Gujarat; Maharashtra; Haryana; Punjab; Uttar Pradesh; West Bengal	6.0	9.0
	-do-	Andaman and Nicobar; Andhra Pradesh; Dadra and Nagar-Haveli; Goa, Daman and Diu; Kerala, Himachal Pradesh; Lakshadweep; Tamilnadu; Madhya Pradesh; Manipur; Karnataka; Nagaland; NEFA; Orissa; Pondicherry; Rajasthan; Tripura	5.0	9.0
Cow milk	-do-	Chandigarh; Haryana; Punjab	4.0	8.5
	-do-	Andaman and Nicobar; Andhra Pradesh; Assam; Bihar; Dadra and Nagar-Haveli; Delhi; Gujarat; Goa, Daman and Diu; Himachal Pradesh; Kerala; Madhya Pradesh; Maharashtra; Tamilnadu; Karnataka; Manipur; Nagaland; NEFA; Pondicherry; Rajasthan; Tripura; Uttar Pradesh; West Bengal; Lakshadweep	3.5	8.5

*Milk fat.

†Milk-solids-not-fat.

Class of milk	Designation	Locality	Minimum	
			% MF*	% MSNF†
		Orissa	3.0	9.0
Goat or sheep milk	Raw, pasteurized, boiled, flavoured and sterilized	Chandigarh; Haryana; Kerala; Madhya Pradesh; Maharashtra; Punjab; Uttar Pradesh	3.5	9.0
	-do-	Andaman and Nicobar; Andhra Pradesh; Assam; Bihar; Dadra and Nagar-Haveli; Delhi; Goa, Daman and Diu; Gujarat; Himachal Pradesh; Lakshadweep; Tamilnadu; Karnataka; Manipur; Nagaland; NEFA; Pondicherry; Orissa; Rajasthan; Tripura; West Bengal	3.0	9.0
Standardized milk		All India	4.5	8.5
Recombined milk		All India	3.0	8.5
Toned milk		All India	3.0	8.5
Double toned milk		All India	1.5	9.0
Skim milk	-do-	All India	Not more than 0.5	8.7

Note. (i) When milk is offered for sale without any indication of the class, the standards prescribed for buffalo milk shall apply.

(ii) The heat-treatment for the various designated milks shall be as follows:

Designation	*Heat-treatment*
Raw	Nil
Pasteurized	Pasteurization
Boiled	Boiling
Flavoured	Pasteurization or sterilization
Sterilized	Sterilization

1.5 Composition

(a) *Milk constituents.* The constituents of milk may be listed diagrammatically as in Fig. 1.1.

The 'major' constituents of milk are: water, fat, protein, lactose, ash or mineral matter. The 'minor' constituents are: phospholipids, sterols, vitamins, enzymes, pigments, etc. The 'true' constituents are: milk fat, casein, lactose.

(b) *Composition of milk*

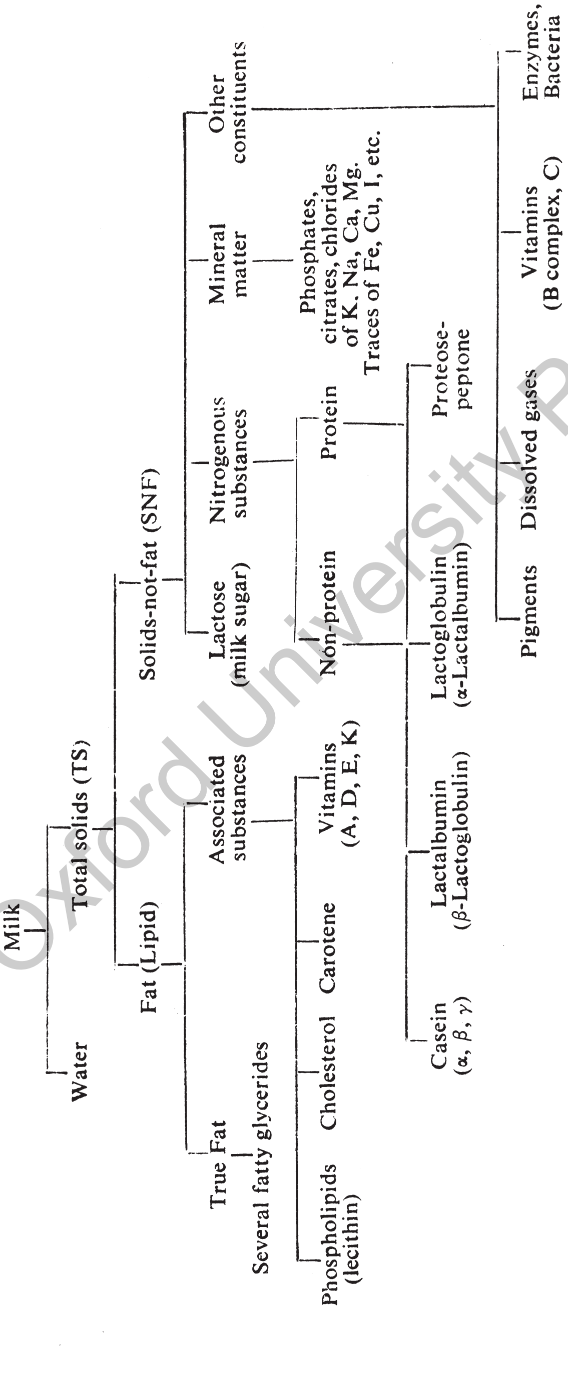
(i) The average chemical composition of milk of different species is given in Table 1.10.

TABLE 1.10

Chemical composition of milk of different species

Name of species	Percentage composition				
	Water	Fat	Protein	Lactose	Ash
Ass	90.0	1.3	1.7	6.5	0.5
Buffalo	84.2	6.6	3.9	5.2	0.8
Camel	86.5	3.1	4.0	5.6	0.8
Cat	84.6	3.8	9.1	4.9	0.6
Cow (foreign)	86.6	4.6	3.4	4.9	0.7
Dog	75.4	9.6	11.2	3.1	0.7
Elephant	67.8	19.6	3.1	8.8	0.7
Ewe	79.4	8.6	6.7	4.3	1.0
Goat	86.5	4.5	3.5	4.7	0.8
Guinea-pig	82.2	5.5	8.5	2.9	0.9
Human	87.7	3.6	1.8	6.8	0.1
Llama	86.5	3.2	3.9	5.6	0.8
Mare	89.1	1.6	2.7	6.1	0.5
Porpoise	41.1	45.8	11.2	1.3	0.6
Reindeer	68.2	17.1	10.4	2.3	1.5
Sow	89.6	4.8	1.3	3.4	0.9
Whale	70.1	19.6	9.5	—	1.0

SOURCE: *Chemistry of Milk* by Davies (1939).



SOURCE: *A Text-book of Dairy Chemistry* by Ling (1948).

Fig. 1.1 Milk Constituents

(ii) The average chemical composition of milk of a few breeds of Indian cows and the Murrah buffalo is given in Table 1.11.

TABLE 1.11

Chemical composition of milk of Indian breeds

Breed of cow/buffalo	Percentage composition				
	Water	Fat	Protein	Lactose	Ash
Sindhi	86.07	4.90	3.42	4.91	0.70
Gir	86.44	4.73	3.32	4.85	0.66
Tharparkar	86.58	4.55	3.36	4.83	0.68
Sahiwal	86.42	4.55	3.33	5.04	0.66
Murrah	83.63	6.56	3.88	5.23	0.70

SOURCE: *IDRI Annual Report* (1948).

Note. See Appendix II for more information on the composition of buffalo milk.

(iii) The average chemical composition of milk of some foreign breeds of cows is given in Table 1.12.

TABLE 1.12

Chemical composition of milk of foreign breeds of cow

Breed	Percentage composition				
	Water	Fat	Protein	Lactose	Ash
Holstein	87.74	3.40	3.22	4.87	0.68
Shorthorn	87.19	3.94	3.32	4.99	0.70
Ayrshire	87.10	4.00	3.58	4.67	0.68
Brown Swiss	86.59	4.01	3.61	5.04	0.73
Guernsey	85.39	4.95	3.91	4.93	0.74
Jersey	85.09	5.37	3.92	4.93	0.71

SOURCE: *The Fluid-Milk Industry* by Henderson (1971).

(iv) The detailed composition of milk is given in Table 1.13.

TABLE 1.13

Detailed composition of milk

Constituents or group of constituents	Approx. concentration (Weight per litre of milk)
Water	860 to 880 g
Lipids in Emulsion Phase	
Milk fat (a mixture of mixed triglycerides)	30 to 50 g
Phospholipids (lecithins, cephalins, sphingomyelins, etc.	0.30 g
Sterols	0.10 g
Carotenoids	
Vitamins A, D, E and K	
Proteins in Colloidal Dispersion	
Casein (α, β, γ fractions)	25 g
β-lactoglobulin(s)	3 g
α-lactalbumin	0.7 g
Albumin, pseudoglobulin, etc.	
Enzymes (catalase, peroxidase, phosphatases, amylases, lipases, proteases, etc.)	
Dissolved materials	
Carbohydrates	
Lactose (α and β)	45 to 50 g
Glucose	50 mg
Inorganic and Organic Ions and Salts	
Calcium*	1.25 g
Phosphate (as PO_4)	2.10 g
Citrates* (as citric acid)	2.00 g
Chloride	1.00 g
Sodium, potassium, magnesium, etc.	
Water-soluble Vitamins	
Thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, biotin, folic acid, vitamin B_{12}, etc.	
Ascorbic acid	
Nitrogenous Materials (not Proteins or *Vitamins)*	
Ammonia, amino-acids, urea, creatine or creatinine, uric acid, etc.	
Gases (milk exposed to air)	
Carbon dioxide, oxygen, nitrogen, etc.	
Trace Elements	
Those usually present are copper, iron, etc.	

*Partly in colloidal dispersion.

SOURCE: *Principles of Dairy Chemistry* by Jenness and Patton (1969).

1.6 Factors Affecting Composition of Milk

(a) Milk differs widely in composition. All milks contain the same kind of constituents, but in varying amounts. Milk from individual cows shows greater variation than mixed herd milk. The variation is always greater in small herds than in large ones. In general, milk fat shows the greatest daily variation, then comes protein, followed by ash and sugar.

(b) The factors affecting the composition of milk are:

(i) *Species.* Each species yields milk of a characteristic composition.

(ii) *Breed.* In general, breeds producing the largest amounts of milk yield milk of a lower fat percentage.

(iii) *Individuality.* Each cow tends to yield milk of a composition that is characteristic of the individual.

(iv) *Interval of milking.* In general, a longer interval is associated with more milk with a lower fat test.

(v) *Completeness of milking.* If the cow is completely milked, the test is normal; if not, it is usually lower.

(vi) *Frequency of milking.* Whether a cow is milked two, three or four times a day, it has no great effect on the fat test.

(vii) *Irregularity of milking.* Frequent changes in the time and interval of milking result in lower tests.

(viii) *Day-to-day milking.* May show variations for the individual cow.

(ix) *Disease and abnormal conditions.* These tend to alter the composition of milk, especially when they result in a fall in yield.

(x) *Portion of milking.* Foremilk is low in fat content (less than 1 per cent), while strippings are highest (close to 10 per cent). The other milk constituents are only slightly affected on a fat-free basis.

(xi) *Stage of lactation.* The first secretion after calving (colostrum) is very different from milk in its composition and general properties. The change from colostrum to milk takes place within a few days.

(xii) *Yield.* For a single cow, there is a tendency for increased yields to be accompanied by a lower fat percentage, and vice versa.

(xiii) *Feeding.* Has temporary effect only.

(xiv) *Season.* The percentages of both fat and solids-not-fat show slight but well-defined variations during the course of the year.

(xv) *Age.* The fat percentage in milk declines slightly as the cow grows older.

(xvi) *Condition of cow at calving.* If the cow is in good physical condition when calving, it will yield milk of a higher fat percentage than it would if its physical condition was poor.

(xvii) *Excitement.* Both yield and composition of milk are liable to transient fluctuations during periods of excitement, for whatever reason.

(xviii) *Administration of drugs and hormones.* Certain drugs may effect temporary change in the fat percentage; injection or feeding of hormones results in increase of both milk yield and fat percentage.

1.7. Food and Nutritive Value of Milk

Milk is an almost ideal food.* It has high nutritive value. It supplies body-building proteins, bone-forming minerals and health-giving vitamins and furnishes energy-giving lactose and milk fat. Besides supplying certain essential fatty acids, it contains the above nutrients in an easily digestible and assimilable form. All these properties make milk an important food for pregnant mothers, growing children, adolescents, adults, invalids, convalescents and patients alike.

(a) *Proteins.* Milk proteins are complete proteins of high quality, i.e. they contain all the essential amino-acids in fairly large quantities.

(b) *Minerals.* Practically all the mineral elements found in milk are essential for nutrition. Milk is an excellent source of calcium and phosphorus, both of which, together with vitamin D, are essential for bone formation. Milk is rather low in iron, copper and iodine.

(c) *Vitamins.* These are accessory food factors which are essential for normal growth, health and the reproduction of living organisms. Milk is a good source of vitamin A (provided the cow is fed sufficient green feed and fodder), vitamin D (provided the cow is exposed to enough sunlight), thiamine,

*The drawbacks are: it is very bulky; and is deficient in iron, copper and vitamin C.

riboflavin, etc. However, milk is deficient in vitamin C.

(d) *Fat.* Milk fat (lipid) plays a significant role in the nutritive value, flavour and physical properties of milk and milk products. Besides serving as a rich source of energy, fat contains significant amounts of so-called essential fatty acids (linoleic and arachidonic). The most distinctive role which milk fat plays in dairy products concerns flavour. The rich pleasing flavour of milk lipids is not duplicated by any other type of fat. Milk fat imparts a soft body, smooth texture and rich taste to dairy products. Lastly, milk lipids undoubtedly enhance the consumer acceptability of foods; they also serve the best interests of human nutrition through the incentive of eating what tastes good.

(e) *Lactose.* The principal function of lactose (carbohydrate) is to supply energy. However, lactose also helps to establish a mildly acidic reaction in the intestine (which checks the growth of proteolytic bacteria) and facilitates assimilation.

(f) *Energy value.* The energy-giving milk constituents and their individual contributions are as follows:

Milk fat	9.3 C/g
Milk protein	4.1 C/g
Milk sugar	4.1 C/g

where 1 C (Food Calorie) = 1000 c (small calorie).

Note. The energy value of milk will vary with its composition. On average, cow milk furnishes 75 C/100 g and buffalo milk 100 C/100 g.

(g) *Effect of processing.* (i) Pasteurization carried out with reasonable care has no effect on vitamin A, carotene, riboflavin and a number of remaining vitamins B, and vitamin D. Of the remainder, a 10 per cent loss of thiamine and a 20 per cent loss of ascorbic acid may be expected. (ii) Sterilization increases the losses of thiamine and ascorbic acid to 30–50 per cent and 50 per cent respectively, though the remaining vitamins are but little affected.

(h) A balanced diet is essential for proper health and growth. The role of milk and milk products in providing the nutrients required for a balanced diet is indicated in Table 1.14.

TABLE 1.14

Role of milk and milk products in a balanced diet

Nutrients	Purpose	Sources
Proteins	Essential for muscle building and repair; give the body energy and heat	Meat, poultry, fish, *milk*, *cheese*, beans, peas, nuts
Carbohydrates	Body energy and heat	Bread, cereals, pastry, sugar, vegetables, fruit
Fats	-do-	*Butter*, *ghee*, oils
Minerals	Bone, teeth, body cells	*Dairy products*, fruit, vegetables
Vitamin A	Growth, health of the eyes, structure and function of the skin and mucous membrane	*Fat-rich dairy products*, eggs, spinach, carrots, tomatoes, fish liver oils
Vitamin B_1 (Thiamine)	Growth, aids appetite, prevents beri-beri, function of the nervous system	Whole grains, eggs, green vegetables, yeast, liver, kidney
Vitamin B_2 (Riboflavin)	Growth, health of skin and mouth, functioning of the eyes	*Milk*, cabbage, carrots, spinach, liver, eggs, yeast, lean meat, prunes
Niacin	Functioning of the stomach, intestines and nervous system	Meat, heart, kidney, liver, eggs, fish, *milk*, peanuts, yeast
Vitamin C	Aids bones and teeth, prevents scurvy	Citrus fruit, maize, tomatoes, lettuce, cabbage
Vitamin D	Aids in calcium-absorption which strengthens bones, prevents rickets	Eggs, *milk*, fish liver oils

1.8 Physico-Chemical Properties of Milk Constituents

A. *Major Milk Constituents*

(a) *Water.* Constitutes the medium in which the other milk constituents are either dissolved or suspended. Most of it is 'free', and only a very small portion is in the 'bound' form, being firmly boand by milk proteins, phospholipids, etc.

(b) *Milk fat* (*lipid*). The bulk of the fat in milk exists in the form of small globules, which average approximately 2 to 5 microns in size (range 0.1 to 22 microns). This is an oil-in-water type emulsion. The surface of these fat globules is coated with an adsorbed layer of material commonly known as the fat globule membrane. This membrane contains phospholipids and proteins in the form of a complex, and stabilizes the fat emulsion. In other words, the membrane prevents the fat globules from coalescing but keeps separated from one another. The emulsion may, however, be broken by agitation (at low temperatures), heating, freezing, etc. When milk is held undisturbed, the fat globules tend to rise to the surface to form a cream layer. The thickest cream layer is secured from milks which have a higher fat content and relatively large fat globules (such as buffalo's milk when compared with cow's milk).

Chemically, milk fat is composed of a number of glyceride-esters of fatty acids; on hydrolysis, milk fat furnishes a mixture of fatty acids and glycerol. (That milk fat is a mixture of true fats is established from the fact that it has no sharp melting point.) The fatty acids are saturated or unsaturated. Saturated fatty acids are relatively stable. On the other hand, the unsaturated ones play an important role in the physico-chemical properties of milk fat.

(c) *Milk proteins*. Proteins are among the most complex of organic substances. They are vital for living organisms as they constitute an indispensable part of the individual body cell. Proteins are composed of a large number of amino-acids, some 'essential' and others 'non-essential'. The essential amino-acids are necessary in the diet for the formation of body proteins. On hydrolysis, proteins furnish a mixture of amino-acids. The proteins of milk consist mainly of casein, β-lactoglobulin, α-lactalbumin, etc. Casein exists only in milk and is found in the form of a calcium caseinate-phosphate complex. It is present in the colloidal state. It forms more than 8 per cent of the total protein in milk. It may be precipitated by acid, rennet, alcohol, heat and concentration. Casein itself is composed of α, β, γ fractions. The heterogeneous nature of α-casein can be observed through electrophoresis. α-casein is the component in casein micelle that is responsible for the stabilization of the micelle in milk. Later studies have also revealed that α-casein is composed of at least two sub-fractions, viz., α_s-casein precipitable by calcium-ion under certain conditions and also called 'calcium-sensitive casein'; and K-casein, also called 'calcium-insensitive casein', not precipitable by calcium-ion. K-casein is the richest repository of carbohydrates as against other casein fractions. It is also the site for rennin action.

β-lactoglobulins and α-lactalbumin are also known as whey or serum-proteins. They are also present in the colloidal state and are easily coagulable by heat.

(d) *Milk sugar or lactose.* This exists only in milk. It is in true solution in the milk serum. On crystallization from water, it forms hard gritty crystals. It is one-sixth as sweet as sucrose. Lactose is responsible, under certain conditions, for the defect known as 'sandiness' in ice cream and sweetened condensed milk. Chemically, lactose is composed of one molecule each of glucose and galactose. Lactose occurs in two forms, α and β, both of which occur either as the hydrate or the anhydride. It is fermented by bacteria to yield lactic acid and other organic acids and is important both in the production of cultured milk products and in the spoilage of milk and milk products by souring.

(e) *Mineral matter or ash.* The mineral matter or salts of milk, although present in small quantities, exert considerable influence on the physico-chemical properties and nutritive value of milk. The major salt constituents, i.e. those present in appreciable quantities, include potassium, sodium, magnesium, calcium, phosphate, citrate, chloride, sulphate and bicarbonate; the trace elements include all other minerals and salt compounds. The mineral salts of milk are usually determined after ashing. Although milk is acidic, ash is distinctly basic. Part of the mineral salts occur in true solution, while a part are in the colloidal state.

B. *Minor Milk Constituents*

(a) *Phospholipids.* In milk, there are three types of phospholipids, viz. lecithin, cephalin and sphingomylin. Lecithin, which forms an important constituent of the fat globule membrane, contributes to the 'richness' of flavour of milk and other dairy products. It is highly sensitive to oxidative changes, giving rise to oxidized/metallic flavours. Phospholipids are excellent emulsifying agents, and no doubt serve to stabilize the milk fat emulsion.

(b) *Cholesterol.* This appears to be present in true solution in the fat, as part of the fat globule membrane complex and in complex formation with protein in the non-fat portion of milk.

(c) *Pigments.* These are: (i) fat soluble, such as carotene and xanthophyll, and (ii) water soluble, such as riboflavin. Carotene is the colouring matter of all green leaves, where it is masked by chlorophyll. Carotene (the pure substance of which has a reddish-brown colour) is fat soluble and responsible for the yellow colour of milk, cream, butter, ghee and other fat-rich dairy products. Besides contributing to the colour of cow milk, carotene acts as an anti-oxidant and also as a precursor of vitamin A. One molecule of β-carotene yields two molecules of vitamin A, while α-carotene yields only one.

Dairy animals differ in their capacity to transfer carotene from feeds to milk fat; this varies with species, breed and individuality. Cows in general, and some breeds in particular (such as Guernsey and Jersey), can transfer more carotene from their feed to the milk fat than buffaloes, who do not seem to possess this capacity. Hence buffalo milk is white in colour. (The carotinoid content of buffalo milk varies from 0.25 to 0.48/ug/g, while that of cow milk may be as high as 30/ug/g.)

Riboflavin, besides being a vitamin, is a greenish-yellow pigment which gives the characteristic colour to whey. (Earlier, the terms 'lactochrome' and 'lactoflavin' were used instead of riboflavin.)

(d) *Enzymes.* These are 'biological catalysts' which can hasten or retard chemical changes without themselves participating in the reactions. The enzymes are protein-like, specific in their actions, and inactivated by heat; each enzyme has its own inactivation temperature. The important milk enzymes and their specific actions are as follows: (i) Analase (diastase)—starch splitting; (ii) Lipase—fat splitting, leading to rancid flavour; (iii) Phosphate—capable of splitting certain phosphoric acid esters (basis of phosphatase test for checking pasteurization efficiency); (iv) Protease—protein splitting; (v) Peroxidase and Catalase—decomposes hydrogen peroxide.

(e) *Vitamins.* Although present in foods in very minute quantities, these are vital for the health and growth of living organisms. As of today, over 25 vitamins have been reported. Those found in milk are: fat-soluble vitamins A, D, E and K; and water-soluble vitamins of the 'B Complex' group (such as thiamine or B_1, riboflavin or B_2, pantothenic acid, niacin, pyridoxine or B_6, biotin.

B_{12}, folic acid, etc.) and vitamin C (ascorbic acid). Absence of vitamins in the diet over prolonged periods causes 'deficiency diseases'.

1.9 Physico-Chemical Properties of Milk

A. *Physical State of Milk*

Water is the continuous phase in which other constituents are either dissolved or suspended. Lactose and a portion of the mineral salts are found in solution, proteins and the remainder of the minerals in colloidal suspension and fat as an emulsion.

B. *Acidity and pH of Milk*

(a) *Acidity.* Freshly-drawn milk is amphoteric to litmus, i.e. it turns red litmus blue and blue litmus red. However, it shows a certain acidity as determined by titration with an alkali (sodium hydroxide) in the presence of an indicator (phenolphthalein). This acidity, also called Titratable Acidity (T.A.) as it is determined by titration, is known as 'natural' or 'apparent' acidity and is caused by the presence of casein, acid-phosphates, citrates, etc., in milk. The natural acidity of individual milk varies considerably depending on species, breed, individuality, stage of lactation, physiological condition of the udder, etc., but the natural acidity of fresh, herd milk is much more uniform. The higher the solids-not-fat content in milk, the higher the natural acidity (N.A.) and vice versa. The titrable acidity of cow milk varies on an average from 0.13 to 0.14 per cent and buffalo milk from 0.14 to 0.15 per cent. 'Developed' or 'real' acidity is due to lactic acid, formed as a result of bacterial action on lactose in the milk. Hence the titrable acidity of stored milk is equal to the sum of natural acidity and developed acidity. The titrable acidity is usually expressed as a 'percentage of lactic acid'.

(b) *pH.* The pH of normal, fresh, sweet milk usually varies from 6.4 to 6.6 for cow milk and 6.7 to 6.8 for buffalo milk. Higher pH values for fresh milk indicate udder infection (mastitis) and lower values, bacterial action.

Note. The acidity and pH of fresh milk vary with: (i) species; (ii) breed; (iii) individuality; (iv) stage of lactation; (v) health of the animal, etc.

C. *Density and Specific Gravity*

Whereas density of a substance is its mass (weight) per unit volume, specific gravity is the ratio of density of the substance to density of a standard substance (water). Since the density of a substance varies with temperature, it is necessary to specify the temperature when reporting densities or specific gravities. The specific gravity of a substance (when referred to water at 4°C) is numerically equal to the density of that substance in the metric system. The specific gravity of milk is usually expressed at 60°F (15.6°C).

The density or specific gravity of milk may be determined by either determining the weight of a known volume or the volume of a known weight. The weight of a known volume may be determined either with a pycnometer or with a hydrostatic balance; while the volume of a known weight is determined by using lactometers, the scale of which is calibrated not in terms of volume but as a function of either density or specific gravity. The common types of lactometers are Zeal, Quevenne, etc.

Milk is heavier than water. The average specific gravity ranges (at 60°F) from 1.028 to 1.030 for cow milk, 1.030 to 1.032 for buffalo milk and 1.035 to 1.037 for skim milk. The specific gravity of milk is influenced by the proportion of its constituents (i.e. composition), each of which has a different specific gravity approximately as follows: water—1.000; fat—0.93; protein—1.346; lactose—1.666; and salts—4.12 (solids-not-fat—1.616).

As milk fat is the lightest constituent, the more there is of it the lower the specific gravity will be, and vice versa. However, although buffalo milk contains more fat than cow milk, its specific gravity is higher than the latter's; this is because buffalo milk contains more solids-not-fat as well, which ultimately results in a higher specific gravity.

The specific gravity of milk is lowered by addition of water and cream, and increased by addition of skim milk or removal of fat.

The percentage of total solids or solids-not-fat in milk is calculated by using the following formula, *vide IS*: *1183*, 1965 (Revised).

$$\%\ \text{TS} = 0.25D + 1.22F + 0.72$$

$$\%\ \text{SNF} = 0.25D + 0.22F + 0.72$$

where, $D = 1000(d - 1)$

d = density of sample of milk at 20°C (68°F)

F = fat percentage of sample.

Note. The specific gravity of milk should not be determined for at least one hour after it is drawn from the animal; else a lower-than-normal value will be obtained (due to the Recknagel phenomenon).

D. *Freezing Point of Milk*

Milk freezes at temperatures slightly lower than water due to the presence of soluble constituents such as lactose, soluble salts, etc., which lower or depress the freezing point. The average freezing point depression of Indian cow milk may be taken as 0.547°C (31.02°F) and buffalo milk 0.549°C (31.01°F). Most bulk milk samples have a freezing point depression of 0.530°C (31.05°F); a freezing point depression lower than this value indicates added water. Mastitis milk shows a normal freezing point. The freezing point test of milk is a highly sensitive one and even up to 3 per cent of watering can be detected.

While the freezing point of normal fresh milk is remarkably constant and employed mainly for detection of adulteration of milk with water, souring results in a lowering of the freezing point due to increase in the amount of soluble molecules. Hence the freezing point should be determined on unsoured samples for greatest accuracy. Boiling and sterilization increase the value of freezing point depression, but pasteurization has no effect. The fat and protein contents of milk have no direct effect on the freezing point of milk. The drawbacks of the freezing point test are: (i) it does not detect the addition of skim milk or removal of fat from the milk sample; and (ii) watered milk, which has subsequently soured, may pass the test.

E. *Colour of Milk*

The colour is a blend of the individual effects produced by: (i) the colloidal casein particles and the dispersed fat globules, both of which scatter light, and (ii) the carotene (to some extent xanthophyll) which imparts a yellowish tint. Milk ranges in colour from yellowish creamy white (cow milk) to creamy white (buffalo milk). The intensity of the yellow colour of cow milk depends on various factors such as breed, feeds, size of fat globules, fat percentage of milk, etc. Certain breeds of cow impart a deeper yellow tint to their milk than others. The greater the intake of green feed, the deeper yellow the colour of cow milk. The larger the fat globules and the higher the fat percentage, the greater the intensity of the yellow colour. Skim milk has a bluish, and whey a greenish yellow colour (which in milk is masked by the other constituents present).

Note. (i) The colour of foods is an important aspect of their marketability. Colour has three aspects, viz. tint, intensity and uniformity. Variation in intensity is tolerated as it occurs in practice.

(ii) The colour of an opaque object is the colour it reflects; the colours of the visible spectrum are absorbed. Thus an object is yellow because more yellow light is reflected to the eye than any other colour. (A white object reflects all the colours of light that fall on it, while a black object absorbs them all.)

F. *Flavour*

This is composed of smell (odour) and taste. The flavour of milk is a blend of the sweet taste of lactose and salty taste of minerals, both of which are damped down by proteins. The phospholipids, fatty acids and fat of milk also contribute to the flavour.

Changes in the flavour of milk occur due to type of feed, season, stage of lactation, condition of udder, sanitation during milking and subsequent handling of milk during storage. The sulfydryl compounds significantly contribute to the cooked flavour of heated milks.

Note. A pronounced flavour of any kind is considered abnormal to milk. The sources of abnormal flavours may be: (i) bacterial growth; (ii) feed; (iii) absorbed; (iv) chemical composition; (v) processing and handling; (vi) chemical changes; (vii) addition of foreign material.

1.10 Microbiology of Milk

A. *Introduction*

Nearly all the changes which take place in the flavour and appearance of milk, after it is drawn from the cow, are the result of the activities of micro-organisms. Of these, the most important in dairying are bacteria, mould, yeast and virus—the first one predominating. Micro-organisms are visible only with the aid of a microscope. A few are desirable, while most cause undesirable changes; a relatively small proportion are disease-producing types, and are called 'pathogens'. In the dairy industry considerable effort is expended in controlling micro-organisms which cause spoilage. The greater the bacterial count in milk, i.e. the greater the number of bacteria per ml of milk, the lower is its bacteriological quality.

Bacteria are microscopic, unicellular fungi (plants without chlorophyll) which occur principally in the form of spherical, cylindrical or spiral cells and which reproduce by transverse fission. In milk and its products, the spherical and cylindrical forms are predominant. Most bacteria vary from 1 to 5 microns in size. Although individual bacterial cells are invisible to the naked eye, they form bacterial 'colonies' (consisting of a large number of individual cells) which are visible. Bacteria are found nearly everywhere in nature. They are found in large numbers in the soil, sewage, decaying plants or animals; and are also present in air, water, etc. Under favourable conditions, bacteria multiply very rapidly and may double their number in 15 minutes or less. Some bacteria also form 'spores', which are tough resistant bodies within the bacterial cell. Spores, when placed in an environment favourable to growth, form new vegetative cells. Spore-forming bacteria cause trouble in the dairy industry because of their resistance to pasteurization and sanitization procedures.

Moulds are multi-cellular, differing greatly in most respects from bacteria. Although the individual cells are not visible to the naked eye, at maturity they may be observed readily as 'Mycelium'. They are found in soil, feeds, manure and poorly-washed utensils. Most spores of moulds are destroyed by pasteurization. They are of considerable importance in cheese-making and are responsible for some defects in butter and other milk products.

Yeasts are unicellular but are somewhat larger in size than bacteria. Spores of yeasts are readily destroyed during pasteurization.

Viruses include all ultra-microscopic forms of life. In the dairy industry, only those viruses that are parasitic on lactic acid bacteria and known as Starter Bacteriophage (or simply Phage) are of special importance. The viruses range in size from 0.22 to 0.23 microns. The lactic phages are usually not destroyed by normal pasteurization of milk employed for cheese and cultured buttermilk, but they can be destroyed by higher heat-treatment.

B. *Growth of Micro-Organisms*

In microbiology, growth refers to increase in numbers. Milk drawn from a healthy cow already contains some bacteria. Their numbers multiply during production and handling, depending on the cleanliness of these operations. Subsequently, their numbers may grow still further (either substantially or only slightly) depending on storage conditions.

The changes which take place in the physico-chemical properties of milk are the result of the activities of the individual microbial cells during their period of growth (development and reproduction) or of substances produced during such activity.

(a) *Stages of growth.* The growth of micro-organisms normally takes place in the following stages: (i) initial stationary phase; (ii) lag phase (phase of adjustment); (iii) accelerated growth phase (log phase); (iv) maximum stationary phase; and (v) phase of accelerated death.

(b) *Factors influencing growth.* The growth of micro-organisms is influenced by the following factors: (i) *Food supply.* Milk and most dairy products furnish all the food requirements of micro-organisms. (ii) *Moisture.* Milk contains adequate moisture (dry products, due to their low moisture content, keep longer). (iii) *Air.* Supplies oxygen to aerobic types of bacteria and to moulds in general. (iv) *Acidity or pH.* Most common types prefer a pH from 5.6 to 7.5. (v) *Preservatives.* These check or destroy growth, depending on their concentration. (vi) *Light.* Is more or less harmful. (vii) *Concentration.* High sucrose or salt content in product checks growth, and (viii) *Temperature.* An important means for controlling growth. Each species of micro-organism has its optimum, maximum and minimum temperatures of growth.

According to their optimum growth temperatures, bacteria can be classified into:

Psychrotropic. Can grow at refrigeration temperatures (5–7°C).

Mesophilic. Can grow at temperatures ranging between 20°C and 40°C.

Thermophilic (heat loving). Can grow at temperatures above 50°C.

Note. In general, low temperatures (below 10°C) retard microbial growth. Hence milk and dairy products should be adequately refrigerated to prevent rapid spoilage. The optimum growth rate of the majority of micro-organisms will be found at temperatures between 15 and 38°C. Most micro-organisms are destroyed at high temperatures, viz. 60°C or above.

(c) *Products of microbial growth.* These are: (i) enzymes; (ii) decomposition products (of fats, proteins, sugars, etc.); (iii) pigments; (iv) toxins; and (v) miscellaneous changes.

(d) *Results of microbial growth in milk.* These are:

(i) *Souring.* Most common. Caused by transformation of lactose into lactic and other volatile acids and compounds, principally by lactic acid bacteria. (The development of a sour acid flavour is not due to lactic acid, which is odourless, but due to volatile acids and compounds.)

(ii) *Souring and gassiness.* Caused by Coli group, which are commonly found in soil, manure, feed, etc., and therefore indicate contamination of milk and dairy products.

(iii) *Aroma production.* Due to production of desirable flavour compounds such as diacetyl (in ripened-cream-butter).

(iv) *Proteolysis.* Protein decomposition leading to unpleasant odours. (Sometimes desirable flavours may develop, as in cheese curing.)

(v) *Ropiness.* Long threads of milk are formed while pouring.

(vi) *Sweet curdling.* Due to production of a rennin-like enzyme, which curdles milk without souring.

C. *Destruction of Micro-Organisms*

This may be done by means of:

(i) *Heat.* Most widely used. Different types of heat-treatment (temperature-time combination) are employed, such as pasteurization, sterilization, etc.

(ii) *Ionizing radiation.* Such as ultra-violet rays, etc.

(iii) *High frequency sound waves.* Such as supersonic and ultrasonic.

(iv) *Electricity.* Here, the micro-organisms are destroyed, actually, by the heat generated.

(v) *Pressure.* Should be about 600 times greater than atmospheric pressure, and

(vi) *Chemicals.* These include acids, alkalis, hydrogen peroxide, halogens, etc.

1.11 Milk and Public Health

It is well established that milk can be a potential carrier of disease-producing organisms. Milk-borne epidemics have occurred in the past throughout the world. Unless proper precautions are taken, such outbreaks of milk-borne diseases can occur anywhere, any time, especially if raw milk is consumed.

Diseases which are known to be transmissible through milk are listed below, together with the manner in which they may enter the milk:

(i) *Infection of milk directly from the cow.* These diseases are essentially bovine. The causative organisms enter the milk through the mammary glands or through faecal contamination, and may cause a diseased condition in persons who consume the milk. Examples: Bovine tuberculosis; Undulant fever or Malta fever; etc.

(ii) *Infection from man to cow and then to milk.* These diseases are essentially human, but can become established in the cow's udders. Examples: Septic sore throat; Scarlet fever, Diphtheria; etc.

(iii) *Direct contamination of milk by human beings.* These diseases may be transmitted to the milk by direct contamination through human contact, either by carriers or patients. Examples: Septic sore throat; Scarlet fever; Typhoid fever; Paratyphoid fever; Dysentery; Gastroenteritis; Diphtheria; etc.

(iv) *Indirect contamination of milk by human beings.* These are human diseases, the pathogenic organisms of which enter the milk through contaminated bottles or other utensils, water supply, insects and dust. Examples: Typhoid or Paratyphoid fever; Dysentery or Diarrhoea; etc.

1.12 Safeguarding the Milk Supply

Whereas 'cleanliness' implies freedom from extraneous matter (such as manure, dust, etc.), 'safety' means freedom from pathogenic micro-organisms. For human consumption, milk that is both clean and safe is highly desirable.

The sanitation of the milk supply can be safeguarded in two ways: (a) production and handling of raw milk in such a manner as to prevent its contamination by pathogenic organisms. This will require: (i) ensuring the health of dairy cattle by various control measures; (ii) safeguarding the health of employees by regular medical examination; (iii) protection of the water supply from contamination by pathogenic organisms; (iv) flies and their control, etc. Examples: 'Certified milk', 'Grade A raw milk', etc.

(b) Pasteurization of milk, so as to kill all pathogenic organisms and avoidance of any post-pasteurization contamination. (This will be discussed later.)

1.13 Clean Milk Production

(a) The following standards, *vide* Table 1.15, are suggested as a guide for grading raw milk in this country:

TABLE 1.15

Bacteriological standards of raw milk

SPC/ml (or g)	Grade
Not exceeding 200,000	Very good
Between 200,000 and 1,000,000	Good
Between 1,000,000 and 5,000,000	Fair
Over 5,000,000	Poor

SOURCE: *IS : 1479* (Part III), 1962.

Note. The pasteurized milk (at the plant, in its final container) should have a SPC/ml (or g) not exceeding 30,000.

(b) The sources of contamination of milk and their control have been given in Table 1.16.

TABLE 1.16

Sources of contamination of milk and their control

Sources of Contamination	Control Measures
Interior of the udder	(i) Check for mastitis (ii) Discard foremilk
Exterior of the cow, particularly udder and flanks	(i) Wash and wipe udder (ii) Clip the udder and flanks (iii) Dry milking (iv) Use small-top milk-pail
Barn air and dust	(i) Keep milk covered
Flies and other vermin	(i) Eliminate breeding places (ii) Fly control with fly sprays, fly traps, etc.
The milker	(i) Clean habits (ii) Dry milking
Utensils	(i) Clean, sanitize and dry before use

SOURCE: *Market Milk* by Sommer (1952).

Note. Besides the above, two other control measures are used, viz. straining and cooling (which will be discussed later).

1.14 Buying and Collection of Milk

A. *Buying*

Various methods for buying milk are employed, singly or in combination, as given below:

(a) *Payment according to weight or volume* (also known as a flat rate). *Advantages*: (i) saves time; (ii) simple to calculate. *Disadvantage*: (i) encourages watering or skimming. Payment by weight is preferred to payment by volume as the former is not affected by either foam or specific gravity. (It is popular in the unorganized sector.)

(b) *Payment according to the fat content of milk* (includes, among others, the straight fat method of payment). *Advantages*: (i) practical; (ii) discourages adulteration with water. *Disadvantages*: (i) does not prevent removal of skim milk; (ii) does not take into account the solids-not-fat content of milk. (Practised by most dairies.)

(c) *Payment according to the use made of milk.* This practice is followed mainly for milk products.

(d) *Payment of premiums.* Usually confined to market milk. Based on quality of milk as measured by (i) sediment test; (ii) flavour score; (iii) bacterial count or Methylene Blue Reduction Time. (Encourages the production of high-grade milk.)

(e) *Payment according to the cost of production.* Complicated, although rational.

Note. The urgent need for a sound pricing policy for milk and milk products in this country is being increasingly realized by dairy planners today. The problem, no doubt, is complicated, as the price has to be acceptable to the producers, processors and manufacturers, distributors and finally consumers. Further, the approach must be of long-range significance to dairy development.

A rational milk pricing policy should ensure: a guaranteed price and market to the producers throughout the year, which will be an incentive to them to produce more milk; a regular supply of wholesome milk at reasonable rates to the consumers; and an attractive margin of profit to the milk processors and product manufacturers.

In fixing the producers' price for fluid milk, the following basic considerations have to be kept in view: the price should be related to the cost of milk production and ensure a fair margin of profit to the producers; it should take into account the seasonal variation in production (supply) and demand; and should be linked with the consumers' price index, taking into account general market trends.

From the point of view of the milk processor/milk-product manufacturer, the price of milk should take into account the following: the stage of operation of the plant; the costs of transportation, processing/manufacturing and distribution; plant capacity so as to utilize all surplus milk in the milk-shed area; and the market objective of the plant, including its programme of product diversification.

The consumers' price has to be fixed after consideration of the size of the population that is to be covered by the milk scheme;

the distribution of people in different occupational and income groups (viz., lower, middle and higher) that are to be served; and the total cost of transportation, processing/manufacturing and distribution (which should be adequately covered, besides leaving a reasonable margin of profit to the milk plant).

It is, therefore, necessary to strike a balance between the producers' price which is to serve as a production incentive and the consumers' price which should be within the purchasing power of the average consumer throughout the year.

At present each milk plant or dairy product factory has evolved an arbitrary system of milk pricing, which seems to have no relation to the actual cost of milk production. Liquid milk plants have a differential pricing system for flush and lean months based on the fat and SNF contents of milk, with provision for the payment of a premium for a higher fat and SNF content than the specified standard. Dairy product factories purchase milk by and large on a per kilo fat basis at different prices for different seasons.

The minimum standards prescribed by the PFA (1976) rules for cow milk are 3.0 to 4.0 per cent fat and 8.5 to 9.0 per cent solids-not-fat, while those for buffalo milk are 5.0 to 6.0 per cent fat and 9.0 per cent solids-not-fat throughout the country. With a view to encouraging milk production through high yielding indigenous and cross-bred cows, it is necessary to adopt a pricing policy which would provide an adequate incentive for production of cow milk. In this context, the National Dairy Development Board has suggested the two-axis milk pricing policy. Such a policy ensures payment for milk on its compositional quality evaluated rationally on its fat and solids-not-fat components. This would discourage adulteration of buffalo milk and at the same time ensure a common pricing approach to cow and buffalo milks.

However, one difficulty that can be foreseen in this system is the accurate testing of milk at source for its solids-not-fat content. Since the estimation of solids-not-fat in milk is a time-consuming process, research would have to be undertaken to develop a rapid test which could be carried out under field conditions.

The overall pricing policy for milk products should encourage efficiency of production, minimization of costs, quality of the product, etc. Dairy factories should try to create the feeling that the price of producers' milk is not predetermined unilaterally at a fixed rate but varies, rather, with season and quality.*

B. *Collection*

In almost all developed dairying countries, production of milk is confined to rural areas, while demand is mostly urban in nature. Hence milk has to be collected and transported from production points in the milk-shed areas to processing and distribution points in cities.

(a) The common systems for collection (assembling) of milk are as follows:

(i) *By co-operative organizations.* Formed by individual or collective milking societies. Suits producers best as no profit-making middlemen are involved.

(ii) *By contractors.* Less return to producers.

(iii) *By individual producers.* Practical for those situated near processing dairies.

Note. A 'milk-shed' is the geographical area from which a city dairy receives its fluid milk supply. The allocation of definite milk-sheds to individual dairies for the purpose of developing the same is now being considered in India.

(b) *Milk collection-cum-chilling centres/depots.* Normally attached to city dairies.

Objects. These are: (i) to preserve the quality of raw milk supplies, and (ii) to provide easy transport to the processing dairy.

Location. This is guided by: (i) adequate milk production; (ii) adequate (potable) water supply; (iii) proximity to a good road or railway station; (iv) electric supply, and (v) sewage disposal facilities.

Major items of equipment. (i) Milk weigh tank/pan and weigh ing scale (ii) Drop (dump) tank with cover; (iii) Can washer; (iv) Milk pump (sanitary type); (v) Surface/plate cooler; (vi) Refrigeration unit (of suitable capacity); (vii) Cold room (of suitable capacity); (viii) Milk testing unit, etc.

Operational procedure. Essentially this is the same as in a small dairy. On arrival, the milk is graded for acceptance/rejection, weighed, sampled for testing, cooled and stored at a low temper-

*Adapted from: R. K. Patel, 'Sound basis of pricing milk', *Indian Dairyman* 27 (3), 91 (1975).

ature until despatch to the processing dairy. (Detailed discussion follows later in the book.)

1.15 Cooling and Transportation of Milk

A. *Cooling* (On the farm or at the chilling centre)

(a) *Importance.* Milk contains some micro-organisms when drawn from the udder; their numbers increase during subsequent handling. The common milk micro-organisms grow best between 20 and 40°C. Bacterial growth is invariably accompanied by deterioration in market quality due to development of off-flavours, acidity, etc. One method of preserving milk is by prompt cooling to a low temperature.

(b) *Effect of temperature.* Table 1.17 shows the bacterial growth factor in milk at different storage temperatures:

TABLE 1.17

Effect of storage temperature on bacterial growth in milk

Milk held for 18 hours at temperature (°C)	Bacterial growth factor*
0	1.00
5	1.05
10	1.80
15	10.00
20	200.00
25	1,20,000.00

*Multiply initial count with this factor to get final count.

It will be seen from Table 1.17 that 10°C is a critical temperature for milk. Freshly drawn (raw) milk should, therefore, be promptly cooled to 5°C or below and also held at that temperature till processed.

(c) *Principle.* The principle of heat-exchange, i.e. heating and cooling, will be discussed later.

(d) *Methods.*

I. *In-can or can-immersion method.* From carrying-pails, the milk is poured directly into cans through a strainer. When the can is full, it is gently lowered into a tank/trough of cooling water. (*Note*: The water level in the tank should be lower than the level of milk-in-cans, to prevent water entering into the milk.)

Advantages: (i) Not only is the milk cooled, but it also stays cool. and (ii) a much smaller mechanical refrigeration unit is required.

Disadvantages: (i) It cools the milk very slowly, and (ii) there is danger of milk contamination in case tankwater enters milk-in-can.

II. *Surface cooler*. This may be plain-conical, spiral or horizontal-tubular in shape, although the last-named is now commonly used. The milk is distributed over the outer surfaces of the cooling tubes from the top by means of a distributor pipe or trough and flows down in a continuous thin stream. The cooling medium, mostly chilled water, is circulated in the opposite direction through the inside of the tubes. The cooled milk is received below in a receiving trough, from which it is discharged by gravity or a pump.

Advantages: (i) Transfers heat rapidly and efficiently; (ii) is relatively inexpensive; (iii) also aerates the milk, thus improving its flavour.

Disadvantages: (i) Requires constant attention for rate of flow (which must neither be too slow nor too fast); (ii) greater chances of air-borne contamination; (iii) cleaning and sanitization not very efficient, and (iv) slight evaporation losses.

III. *In-tank or bulk-tank cooler*. Used extensively in developed dairying countries like the U.S.A. Properly designed bulk milk tank coolers, which are normally run by a mechanical refrigeration system, will cool the milk rapidly to a low temperature (5°C or below) and automatically maintain this temperature during the storage period. Milk can be poured directly from the milking pail (under Indian conditions) into the tank. Subsequently milk can be drawn into cans or pumped into a tanker, for despatch to the city dairy.

Advantage: Permits collection of producers' milk on alternate days.

Disadvantage: Relatively expensive in initial equipment.

IV. *Milk chilling centres*. Now that electricity is available even in most Indian villages, these have great scope in this country, largely because of predominantly small and scattered milk production. The number of organized dairy farms in India is rather small. Consequently, the centres can provide the only alternative solution to the collection and chilling of village milk. They can profitably be run by the producers themselves through their co-operative organizations.

B. *Transportation*

(a) *Importance.* Under Indian conditions, milk has to be regularly collected and transported twice a day (morning and evening).

(b) *Modes of transport.* These depend upon the carrying load, the distance of collection and local conditions. Their particulars have been given in Table 1.18.

TABLE 1.18

Modes of milk transportation in India

Mode	Optimum load (kg)	Optimum distance (km)	Remarks
Head-load	15–25	3–8	Generally employed for small loads and distances. Important in hilly areas.
Shoulder-sling	up to 40	3–6	Meant for heavier loads but for shorter distances than head-load.
Pack-animal	up to 80	6–10	Ponies, horses and donkeys usually employed.
Bullock-cart	300–400	10–12	Rather slow.
Tonga	250–300	12 or more	Larger quantities transported; faster than head-load, shoulder-sling and pack-animal.
Bicycle	40 or more	15 or more	Quick and handy; easily accessible to milk producer's home.
Cycle-rickshaw	150–200	10 or more	More carrying capacity than bicycle.
Boat	40–200	2–8	Only means of transport when rivers, etc., have to be crossed.
Auto-rickshaw	250–500	15 or more	Greater carrying capacity and faster than cycle-rickshaw.
Motor truck	½ to 3 tonnes	15 or more	Increasingly in use with more road building and improvement programmes.
Railway wagon	11 tonnes or more	80 or more	Great scope in future.
Tankers (road or rail)	5 tonnes or more	80 or more	Great scope in future.

(c) *Road vs Rail Transport.* The individual advantages of each have been stated in Table 1.19.

TABLE 1.19

Individual advantages of road and rail transport

Type of Transport	Advantages
Road	(i) Loading and unloading possible directly at godown of seller and buyer. (ii) Cheaper than rail over short distances. (iii) Less time-consuming.
Rail	(i) Cheaper than road over long distances. (ii) Larger quantity of milk can be handled at a time.

(d) *Can vs Tanker Transport.* The individual advantages of each have been given in Table 1.20.

TABLE 1.20

Individual advantages of can and tanker transport

Type of Transport	Advantages
Can	(i) Handling small quantities of milk possible.
Tanker	(i) Quicker mode of transport; (ii) Lower cost; (iii) Better temperature control; (iv) Less risk of contamination; (v) More time and labour saving; (vi) Lower investment in cans; (vii) Overall saving in detergents, etc.

(e) *Types of containers used.* These are made of:

(i) baked earth
(ii) wood or bamboo
(iii) metal (generally brass)
(iv) galvanized-iron (GI)
(v) second-hand tins (mainly vegetable oil/ghee)

(vi) tinned-iron or aluminium-alloy (used by organized dairies).

(f) *Problems.* The problems in relation to collection and transportation of milk are:

(i) milk is liquid, perishable and bulky;
(ii) small and scattered production of milk;
(iii) tropical climate;
(iv) lack of transport facilities;
(v) lack of countrywide organizations for milk collection and transport;
(vi) vested interests among local milk merchants.

1.16 Action of Milk on Metals

(a) *Introduction.* Milk acts on certain metals, so that a small amount of the metal is dissolved in it. The metallic salts thus formed may give rise to a 'metallic' taste in the milk. Some salts act as catalysts, thus hastening the oxidation of fat and producing an oxidized flavour. These metals are said to taint milk.

The factors which influence the degree of action by milk on the metal are: (i) temperature of milk; (ii) period of contact; (iii) cleanliness and polish of metal; (iv) amount of free air in milk; (v) acidity of milk, etc.

(b) *Selection of metals for dairy equipment.* The metals used for the milk-contact surfaces must, as far as possible, meet the following requirements: they should be (i) non-toxic; (ii) non-tainting; (iii) insoluble (in milk or its products); (iv) highly resistant to corrosion (by milk, cleaning and sanitizing agents, etc.); (v) easy to clean and keep bright; (vi) light yet strong; (vii) good agents of heat transfer; (viii) good in appearance throughout life; (ix) low in cost; (x) non-absorbent, and (xi) durable.

Note. No single metal or alloy meets all these requirements. However, 18 : 8 stainless steel and aluminium alloy are the most satisfactory at present.

The characteristics of the different metals and their alloys used for dairy equipment have been given in Table 1.21.

(c) *Corrosion control.* Corrosion cannot be entirely prevented in dairy equipment, but its rate can be controlled to a large extent. To prevent corrosion of stainless steel surface: (i) keep the surface clean; (ii) permit surface to air-dry, whenever possible; (iii) use cleaners and sanitizers in the lowest concentration and

TABLE 1.21

Characteristics of different metals and their alloys used for dairy equipment

Name of metals and alloys	Type of equipment generally fabricated	Action of milk on metal	Toxicity	Workability (Ease in fabrication of equipment)	Durability (Resistance to corrosion)	Other characteristics
1	2	3	4	5	6	7
Copper and its alloys	Milk pails, coolers, vats, strainers, pipe fittings, milk pumps, pasteurizer coils, etc. (used for tinning only)	Taint milk/dairy products unless coated with tin	Green corrosion product 'Verdigris' is toxic	Soft metal; easy to work with	With tin coating quite durable	(i) High conductivity: which promotes rapid heat transfer (ii) Reasonable in cost (iii) Repaired easily; retinning cheap
Aluminium and its alloys	Milk cans, milk pails, linings for tanks and tankers, etc.	Do not taint milk	Nil	Soft metal; easy to work with	'Impure' aluminium not durable; aluminium alloyed or anodized much more durable	(i) Light-weight: a great advantage (ii) Aluminium quite porous, hence difficult to clean (iii) Suffers corrosion from common alkaline dairy cleaners and sanitizers (iv) Difficult to solder (v) Suffers corrosion from high acid products
Iron and its alloys	(i) Low-carbon steel widely used for bodies of tanks, vats, bottle-washers, conveyors, etc. (ii) Stainless steel (18 : 8) widely used for all milk/dairy product contact surfaces	Pure iron taints milk/dairy product while stainless steel does not	'Rust' slightly toxic	Tough metal; presents problems in fabrication	Stainless steel highly durable	*Stainless steel*: (i) Highly resistant to corrosion by common acids and alkalis (ii) Takes high polish and therefore easy to clean (iii) Corroded by brine and chlorine solution (iv) Welding has to be done to repair cracks etc.

Tin	Used mainly as a 'coating' for milk/dairy product contact surfaces of cans, vats, etc.	Does not taint milk although quite soluble in it	Nil	Too soft to be used for any kind of equipment	Tin coating not durable	(i) Wears off readily by corrosion, abrasion, etc. (ii) Retinning process not at all difficult
Nickel and its alloys	Nickel used as a coating for milk/dairy product contact surfaces of pasteurizing vats, coolers etc. Ni-alloy used in freezing chamber of ice-cream freezers, cylinders and plungers of homogenizers, etc.	Very slight effect on milk flavour although the most soluble in milk among dairy metals	Mildly toxic	Alloy with iron tough and quite difficult to handle during fabrication	Much more durable than tin coating, but more expensive	(i) Corroded by milk acids (lactic) (ii) Not corroded by alkaline washing powders (iii) Most expensive, when compared with chromium and tin
Chromium and its alloys	Coating on various types of equipment for milk/dairy product contact surfaces	Non-tainting	Nil	–do–	–do–	(i) Expensive (ii) Resistant to corrosive action by acid and alkaline cleaners

Note: (i) Glass-enamelled steel vats are also used considerably. Milk does not act upon such surfaces and hence they cause no flavour changes.

(ii) For milk cans, tinned steel is commonly used, mainly for economic considerations, durability, sturdiness, availability, etc. [See *IS–1373* (1967) and *IS–1825* (1971) for milk cans; and *IS–2336* (1963) and *IS–2337* (1963) for milk vats.]

for the shortest duration that will do the desired cleaning job.

Note. (i) When the stainless steel surface is dry and exposed to the atmosphere, an invisible film of chromium oxide forms on it. This film protects it from corrosion. When the film breaks or wears away, the active metal gets exposed and corrodes more easily. This oxide film is self-forming when the stainless steel surface is dry and exposed to air.

(ii) Chlorine and its compounds are very corrosive. Equipment should be sanitized with chlorine solutions, preferably just before it is to be used, so as to avoid prolonged contact, and thus corrosion (pitting).

1.17 Manufacture, Packaging and Storage of Pasteurized Milk

1.17.1 Flow Diagram

Receiving milk
[Grading, Sampling, Weighing, Testing]
|
Pre-heating (35–40°C)
|
Filtration/Clarification
|
Cooling and Storage (5°C or below)
|
Standardization
|
Pasteurization (63°C/30 mts or 72°C/15 sec)
|
Homogenization (2500 psi)
|
Bottling/Packaging
|
Storage (5°C or below)

1.17.2 Details

I. *Receiving milk*

A. *Introduction.* Milk may be delivered to the Milk Plant/ Dairy in cans or tankers (road or rail). The milk in these containers has to be graded, emptied, measured by weight or volume, sampled, and bulked to provide continuity of supply to the pasteurizing equipment.

In the absence of mechanical aids, the cans are off-loaded manually to the tipping point, where the lids/covers are removed and the milk inspected. They are then tipped manually and both cans and lids passed on to a can-washer via a drip saver or drain rack. Where a higher throughput is required, the procedure is mechanized and the cans are unloaded directly from the truck onto the conveyor (power-driven or by gravity-roller) and the tipping, sampling, and weight-recording may be completely automatic.

If milk is measured by weight, as is usual, it is tipped into the weigh tank/pan; this is suspended from a weighing machine, the indicating dial of which is calibrated in weight and so placed that it can be easily seen by the checker. Two weigh tanks can be used for quick reception. The discharge valve has a large diameter so as to permit rapid emptying, and should be easily controlled by the tipper/checker. The milk is discharged into a dump tank placed immediately below the weigh pan; from this, milk may be pumped continuously to a raw-milk storage tank, normally situated at a higher level to give gravity flow to the pasteurizing plant.

The reception of milk from large rail or road tankers is primarily a matter of providing a covered area under which emptying and subsequent cleaning can take place. The tanker outlet must be connected to sanitary piping. The milk may be removed by a milk-pump, situated at a lower level than the tanker, or a compressed-air line may be connected to the top of the tanker and the milk forced out by air pressure. Washing and sanitization of the tanker should follow immediately after emptying is complete. The measurement of milk delivered by tankers can be done either by using a weigh-bridge or flow-meter.

If milk is being received from milk-chilling centres, it has already been graded, weighed, sampled and cooled. It may be weighed and sampled again, or the Centre's report may be used. The latter procedure applies especially to tanker deliveries.

Milk reception should be so planned and the equipment so chosen that intake operations are expedited. This is especially important where large volumes of milk are received. Delays permit deterioration of milk awaiting dumping, increase labour costs and may increase the operating cost of the can-washer. The deliveries of milk should follow a schedule. If the milk is received continuously during the scheduled period, operations in the plant will not be interrupted and employees in the various sections will be fully occupied. The aim should be to complete milk reception within

3–4 hours, especially in tropical countries.

Market milk requires milk of a higher quality (from the standpoint of good health, flavour, sanitary quality, keeping quality and aesthetic quality) than is required by any other branch of the dairy industry. The quality of the incoming (intake) milk greatly influences the quality of the processed milks (or manufactured products).

It is well known that the sanitary quality of milk on the receiving platform/dock depends on its background on the farm, viz., healthy cows, clean milk production, clean utensils, freedom from colostrum, prompt cooling, and refrigerated transport. However, there is need for systematic and thorough inspection of all milk supplies every day by conscientious and experienced milk graders.

When milk is received at the Milk Plant/Dairy, it should be at 5°C or below. The milk should be clean, sweet, of pleasant flavour, free from off-flavours and reasonably free from extraneous material. Contamination with antibiotics, pesticides and other chemicals or metals is highly undesirable. No abnormal milk should be accepted. Acid development is objectionable, for not only does it indicate an excessive bacterial count, but it also reduces the heat-stability of milk.

B. *Milk reception operations.* The operation of receiving milk may be subdivided into: (a) unloading; (b) grading; (c) sampling; (d) weighing; and (e) testing.

(a) *Unloading.* The motor truck carrying the filled milk cans is backed up (or brought aside) to the unloading platform. The milk cans are then unloaded manually. If the level of the truck surface is in line with the platform, the unloading requires the least effort. (No lifting up or down, but only pulling on a level surface.) Then the milk cans are assembled for grading in a definite order, according to each supplier, viz. the contractor or patron. If a milk tanker is being used, it is first properly positioned so that connections can be made conveniently.

(b) *Grading.* This refers to the classification of milk on the basis of quality, for price-fixing purposes. It is well known that the quality of the finished product depends on that of the raw material used. The milk grader is the key man for the proper selection of milk. The principle of grading is based on organoleptic (sensory) tests, such as those for smell (odour), taste, appearance and touch; acidity; sediment, etc. These are included under platform tests.

Note· The term 'Platform Tests' includes all those tests which are performed to check the quality of the incoming milk on the receiving platform, so as to make a quick decision regarding its acceptance/rejection. They are performed on each can/tanker of milk with the object of detecting milk of inferior or doubtful quality, so as to prevent it being mixed with high-grade milk. Sometimes the term 'Rapid Platform Test' is used to refer mainly to the organoleptic or sensory tests which take very little lime to perform.

The technique of grading milk may be described as under:

(i) *Milk tanker* (Road/Rail). Actually the grading should have been done at the milk collection-cum-chilling centre. As the milk should be cold (5°C or below), it is not possible to detect off-odours. Only the appearance can be noted, as testing of raw milk is usually avoided. After thoroughly mixing it for 5–10 minutes, a sample is taken for laboratory testing.

(ii) *Milk can.* The main tests applied to each can of milk consist of smell, appearance and temperature (touch); other tests such as taste (seldom carried out with raw milk) and sediment might be used to substantiate the initial findings. Tests involving time, laboratory facilities and special techniques are best done by the quality control technician, for which a sufficiently large sample is properly taken as the milk is being received. (Even if the cans of milk have been despatched from a chilling centre, it is wise to inspect each can separately.)

The various platform tests are discussed below:

(i) *Smell* (Odour). This furnishes an excellent indication of the organoleptic quality of milk. It can be ascertained very quickly (in just a few seconds). In making the test, the cover of each can is removed, inverted and raised to the nose. The odour/smell will be representative of that in the can. The top of the milk in the can may simultaneously be noted for smell. By replacing the lid and shaking the can vigorously, the test may be repeated. An experienced milk grader with a 'trained nose' usually relies to a great extent in the acceptance/rejection of the intake milk on the odour test alone. The milk should be free from any off-flavours.

(ii) *Appearance.* By regularly observing the milk in each can after the odour test has been made, any floating extraneous matter, off-colour, or partially churned milk may be noted. The milk should be normal in colour, free from churned fat globules and reasonably free from any floating extraneous material.

(iii) *Temperature.* The temperature at which milk is delivered is often an indication of its quality. A daily check on the temperature of milk is helpful in grading the milk on the receiving platform. With practice, the grader can tell with a high degree of accuracy whether or not the milk is sufficiently cold by touching the side of the can. A temperature of 5°C or below is satisfactory.

(iv) *Sediment.* The sediment test shows the visible foreign matter contained in the milk. It need not be made daily, but should be made sufficiently often to ensure a clean milk supply. For this purpose a reliable sediment tester (such as an off-the-bottom sediment tester), by which the work may be expedited, should be selected. The intensity of discoloration and sediment on the pad will depend to some extent upon the manner in which the test is taken. Any method by which maximum sediment will be revealed should be considered satisfactory. A low sediment is desirable.

Note. The sediment test is used as a check on the milk production and handling methods on the farm. A low sediment need not necessarily mean a low bacterial count in milk, although the reverse is often true. (A clean sediment disc does not indicate clean methods; it may be a pointer rather, to the milk having been filtered/strained on the farms.)

(v) *Acidity.* It has already been pointed out that 'natural' or 'apparent' acidity of milk does not make the milk taste sour, nor does it affect the normal properties of milk or jeopardize its quality or its behaviour towards processing heat. However, 'developed' or 'real' acidity does adversely affect the quality of milk.

Note. Determination of the Titrable Acidity of milk (which is equal to Natural Acidity plus Developed Acidity) for deciding acceptance/rejection of milk on the basis of an arbitrarily set limit cannot serve much useful purpose in India today, especially in view of the fact that the milk suppliers are freely adding neutralizers to milk to reduce its acidity. Nevertheless, the 'acidity test' does have its proper place on the milk reception dock; and with the daily incoming milk it is always well to have a certain acidity above which milk should not be accepted. A modified form is known as the 'rapid acidity test'.

(vi) *Lactometer Reading*. The addition of water to milk results in the lowering of its lactometer reading. Hence this test is applied for detection of adulteration of milk with water. As it does not take much time, it is often used as a platform test in the milk collection/chilling centres in this country. However, this test has its drawbacks.

(c) *Sampling*. The importance of securing an accurate and representative sample of milk for subsequent chemical and bacteriological analysis cannot be over-emphasized. While strict precautions regarding sterility of the stirrer, sampler, container, etc., are required for obtaining a bacteriological sample, dryness and cleanliness of the above equipment should suffice for a chemical sample.

The first prerequisite of sampling is thorough mixing of the milk. This can be done with a plunger or stirrer (agitator), operated manually or mechanically in the milk-in-cans or tankers, as the case may be. With the former, a representative sample may also be taken after quick dumping of the milk into the weigh tank, whereby it gets mixed so thoroughly that a representative sample may be taken without further mixing.

Samples may be: individual; composite (mixture of two or more individual lots of milk); drip (representing the entire day's supply); etc. Samplers may be: dipper; tube or proportionate (also known as milk thief); automatic vacuum; drip; etc. The characteristics of these are given in Table 1.22.

If the composite sample is to be successful, the milk must be kept sweet while the sample is being assembled. This is accomplished by use of a preservative. It is a good plan to place the preservative in the empty bottle before milk is added. A wide-mouthed glass bottle with a rubber stopper has been found to be the most reliable and practical container for keeping composite samples of milk or cream. The common preservatives used are: (i) *Mercuric chloride or corrosive sublimate*. This is very poison-

TABLE 1.22

Characteristics of milk samplers

Type	Principle	Advantage	Disadvantage	Remarks
Dipper	Secures 10–15 ml milk	(i) Fairly fast and easy to work with (ii) Quite accurate when milk is mixed adequately before sampling	Inaccurate when wide variations exist in milk lots, both in quality and quantity	Most commonly used. Most useful for cream
Proportionate	Secures aliquot portion of milk	Most accurate	(i) Cumbersome to use (ii) Larger sample bottle needed	Not so commonly used (not so useful for cream)
Automatic vaccum	Secures aliquot portion by vacuum automatically	(i) Very fast in operation (ii) Very accurate	Expensive	Increasingly used in large market milk plants and product factories
Drip	Milk collects in drops in the sampie bottle (which is kept under refrigeration)	Helpful in fat and SNF accounting of the total intake	Not useful for individual sampling	Useful in large product factories

ous. It may be added in the form of tablets, which are coloured (usually bright red) to prevent the milk being mistaken for food. (ii) *Formalin.* This is a 40 per cent solution of formaldehyde. Being in liquid form, it is very convenient to handle. However, it interferes with the fat test. (iii) *Potassium dichromate.* This is not as effective as the above two, but it is easy to handle in dairy plants because it is available in tablet form.

Note. The composite samples should be stored in a cool place away from direct sunlight. Each bottle should be properly labelled.

(d) *Weighing.* This is an essential step in accounting for milk receipts and disposal, making payments for milk, etc. The milk-in-cans is dumped into the weigh tank, either manually or mechanically. The tank is mounted on scales and the scale dial set at zero when the empty tank is on the scale, thus enabling the operator to make a direct reading of the weight of the milk. Automatic printing of the weight is also now becoming common. (Weighing is facilitated by the use of a dial reading or some other indicating scale, rather than a beam scale.)

The milk in tankers (road or rail) may be measured by volume by passing it through a flowmeter; and its measurement converted into weight by multiplying the volume with an agreed density. In case of road milk tankers, another common alternative is to use a weigh-bridge, the tanker being weighed once when it is full, and again after it has been emptied. However, any mud or snow on the tanker should be washed off before weighing, adjustments to fuel or water should not be made between weighings, and the driver and his accoutrements should be either on or off the vehicle on both occasions.

The characteristics of measuring by weight and by volume have been shown in Table 1.23.

TABLE 1.23

Measurement of milk by weight vs volume

Method	Characteristics
By weight	(i) Gives accurate reading, regardless of foam or temperature;
	(ii) Involves considerable initial expense for both apparatus and its installation;
	(iii) Involves problems with maintenance.
By volume	(i) Not so accurate, as affected by foam and temperature, both influencing density;
	(ii) Lower initial expense;
	(iii) Presents maintenance problems;
	(iv) Definitely a factor to be considered in the overall picture of sanitation.

(e) *Testing.* Apart from initially accepted/rejected lots of milk, there are always some of doubtful quality. All the accepted lots have already been properly sampled; these, together with samples of the remaining two categories, have to be tested in the quality control laboratory for the final verdict of acceptance/rejection. Further, a record of the chemical and bacteriological quality of all accepted milk has to be maintained for making payments, etc. (For 'Methods of Test', consult *Indian Standards* : *IS : 1479* (Part I), 1960; (Part II), 1961; (Part III), 1962.)

The common quality control tests have been given in Table 1.24.

TABLE 1.24

Quality control tests for milk and their significance

Name of Test	Purpose	Remark
Acidity	To determine final acceptance/rejection of milk (on the basis of a pre-determined level)	Applied as such, or in a modified form, as a platform test
Ethanol (Alcohol)	To determine the heat-stability of milk	Applied as a platform test
Alcohol-Alizarin	To determine both heat-stability and pH of milk	-do-
COB (Clot-on-boiling)	To determine the heat-stability of milk	-do-
Dye-reduction test (MBR or Resazurin)	To determine the extent of bacterial contamination and growth in milk	2-mts. Resazurin applied as a platform test
DMC (Direct microscopic count)	To identify the types of micro-organisms present in milk	Applied as a laboratory test
SPC (Standard plate count)	To determine the extent of bacterial contamination and growth in milk	-do-
Lactometer	To detect adulteration of milk with water	Applied as a platform test
Freezing point	-do-	Applied as a laboratory test
Fat and/or SNF	To make payment for milk received	-do-

II. *Pre-heating*

This term refers to heating before the operation which follows immediately. The milk is pre-heated for efficient filtration/clarification. Pre-heating becomes essential if the incoming milk is cold, as otherwise the flow of milk is hampered. As the temperature of the milk increases, the viscosity decreases and more efficient filtration/clarification results. The usual temperature of pre-heating is 35–40°C, and the equipment used may be a plate or tubular heater.

III. *Filtration/Clarification*

(a) *Object.* To improve the aesthetic quality of milk by removing visible foreign matter which is unsightly and may therefore cause consumer complaints.

(b) *Principle.* While filtration removes suspended, foreign particles by the straining process, clarification removes the same by centrifugal sedimentation.

(c) *Types of filters and clarifiers.* There are two types of filters/clarifiers, viz., those that operate with cold milk and those operating with warm milk. While the latter is commonly used throughout the world, the former has the following advantages and disadvantage:

Advantages. (i) No need for pre-heating, and (ii) less likelihood of 'soluble' dirt going into the solution.

Disadvantage. The flow of milk is slow.

(d) *General construction and operation of filters and clarifiers.*

Filters. Their important features are: (i) a filter cloth or pad of the desired pore size which can retain the smallest particle; (ii) a frame or support to compress and hold the margins of the cloth or pad, so that milk can pass only through the pores; (iii) a perforated metal or other support for the cloth or pad which will not tear or break under the pressure of the milk; (iv) an enclosure to confine both the unfiltered and filtered milks in a closed system fitted suitably with inlet and outlet connections for sanitary piping; (v) a means of distributing the incoming stream of milk so that it does not damage or tear any part of the cloth or pad by vigorous washing, and (vi) a design so planned that filter cloths or pads can be changed quickly, and all parts are easily accessible for washing.

Where continuous operation is essential, or where large volumes of milk are processed, two or more filters are used so that operations need not be interrupted when it becomes necessary to change the filter cloth. The frequency with which the cloth is changed will depend upon the temperature of the milk, the amount of foreign matter in it, etc. It is best to use filter cloths only once; a washed cloth, besides being a source of contamination, results in inefficient filtration.

Clarifiers. In general appearance and construction, clarifiers are quite similar to centrifugal cream separators. However, the main differences are: (i) in clarifiers, there is only one outlet, while in separators there are two (one for cream and another for skim milk); (ii) the discs in the clarifier bowl are smaller in diameter (so as to provide a large space for the accumulation of slime) than separators, and (iii) the milk distribution holes are at the outer edge of the discs in clarifiers, but near the centre in separators.

(e) *Location of filter/clarifier in the processing line.* In some cases, it is the practice to locate the filter in the raw milk line before the milk enters the pasteurizing plant; in others, the filter is located at a convenient point in the regeneration section where the temperature of the milk may be 50–60°C.

The clarifier may be located in one of the following places in the processing line, as shown in Table 1.25:

TABLE 1.25

Location of clarifier in the processing line

Location	Type of clarification
Between: Reception and Storage Tanks	Cold
Storage Tank and Pasteurizer	Cold
Pre-heater and Pasteurizer	Warm
Regeneration and Heating Section of HTST	Warm
Heating Section and Holding Tube of HTST	Warm

(f) *Relative efficiency.* Clarification removes sediment much more efficiently than filtration; clarifiers remove still finer particles that escape filters.

(g) *Composition of clarifier slime.* While the material retained on the filter cloth includes suspended foreign particles, milk fat, protein and some leucocytes and bacteria, the slime that accumulates in the clarifier bowl consists of foreign matter, milk proteins, leucocytes, fragments of the secreting cells from the udder, fat, calcium phosphate and other ash, bacteria and occasionally red blood corpuscles.

The amount of clarifier slime is influenced by the amount of foreign matter, the condition of the udder, the stage of lactation, the bacterial count and acidity of milk, the clarifying temperature, the velocity of the bowl, and the amount of milk run through the bowl (or the length of time the bowl is run).

The composition of clarifier slime varies considerably due to the factors stated above. Separator slime is usually considered to be identical with clarifier slime. The typical composition of clarifier/separator slime under American conditions is given in Table 1.26.

TABLE 1.26

Composition of clarifier slime

Constituent	Moist Slime (%)
Water	67.3
T.S.	32.7
Fat	1.1
Protein	25.9
Ash	3.6
Lactose	2.1

SOURCE: *Market Milk and Related Products* by Sommer (1952).

Note. The removal of clarifier slime does not affect the composition of milk to a significant extent; the loss in solids resulting from clarification is usually 0.01 per cent or less.

(h) *General remarks*

(i) Both filtration and clarification tend to decrease the depth of the cream layer that will form on milk, and this effect becomes more pronounced as the processing temperature increases.

(ii) Neither filtration nor clarification improve the keeping quality of milk.

(iii) Milk should neither be filtered nor clarified after pasteurization, as this might contaminate it.

Note. Bactofugation is the process of removing 99 per cent of the bacteria in milk by centrifugal force. It is claimed that this method triples the shelf-life of market milk. Generally it removes the bacteria from milk with two centrifugal clarifiers in a series, the first operating at high velocity (20,000 rpm). The process is considered supplementary to pasteurization, for it is still necessary to destroy the bacteria not removed.

IV. *Cooling and storage of raw milk*

A. *Cooling* (In the Dairy)

(a) *Introduction.* The importance of cooling and the effect of temperature have already been discussed (see 1.15). As soon as milk is received in the Plant, it is chilled to 5°C or below and stored cool till used, to prevent deterioration in its bacteriological quality during the interim period.

(b) *Methods* (In the Dairy).

Surface Cooler. Either an Individual Unit or Cabinet type. The latter consists of two or more individual units, compactly assembled, and enclosed in a cabinet. It is usually larger than those used on the farm/chilling centre.

Plate Cooler. For continuous cooling. Commonly used in the dairy industry, especially for large-scale handling. It consists of a number of thin, flat, grooved, stainless steel plates, sealed at the edges with a gasket and clamped tightly within a press. The spaces between the plates are occupied alternately by the milk and the cooling medium (chill water/brine); thus one side of each plate is exposed to milk and the other side to the cooling medium. Plates may be added to provide increased capacity at nominal cost.

Advantages. (i) Cooling (heat-exchange) is quick and efficient; (ii) not exposed to air-borne contamination; (iii) no evaporation losses; (iv) cleaning and sanitization are easy.

Internal Tubular Cooler. For continuous cooling. It consists of a stainless steel tube about 2.5 to 5.0 cm. in diameter surrounded by a similar tube, forming a concentric cylinder. Several such tubes may then be connected in a series to obtain sufficient cooling. The cooling medium flows counter to the milk flow.

Advantages. (i) Cooling is quite efficient; (ii) not exposed to air-borne contamination; (iii) no evaporation losses.

Disadvantages. (i) Cooling efficiency is lower than plate cooler; (ii) larger floor space is needed.

Jacketed vat/tank. For batch cooling, especially of small quantities. It consists of a tank within a tank, with the space between the two being used for circulation of the cooling medium, by either pump or main pressure. An agitator is provided to move the milk (which is in the upper tank) for rapid cooling.

Disadvantages. (i) Cooling efficiency is rather low; (ii) too much agitation is required, which causes churning and impairs the creaming property of milk.

B. *Storage*

(a) *Introduction*. Modern milk plants hold both raw and pasteurized milks for a much longer period than before. Normally the milk storage capacity is equal to one day's intake. This allows a more nearly uniform work-day for processing and bottling operations with less dependence on the time for receiving raw milk.

Storage tanks are used in Milk Plants for the storage of raw, pasteurized, or processed* products, often in very large volumes. Because of the longer periods of holding, storage tanks are among the most important items of equipment. They must be designed for ease in sanitization, preferably by the circulation-cleaning method. In addition, the tanks should be insulated or refrigerated, so that they can maintain the required temperature throughout the holding period. Agitation should be adequate for homogeneous mixing, but gentle enough to prevent churning and incorporation of air.

(b) *Objects*.

(i) To maintain milk at a low temperature so as to prevent any deterioration in quality prior to processing/product manufacture;

(ii) to facilitate bulking of the raw milk supply, which will ensure uniform composition;

(iii) to allow for uninterrupted operation during processing and bottling;

(iv) to facilitate standardization of the milk.

(c) *Types*.

(i) *Insulated or Refrigerated*. In the former, there are 5 to 7.5 cm. of insulating material between the inner and outer linings; in the latter, the space between the two linings is used for circulation of the cooling medium. Another variation of the refrigerated type is the cold-wall tank.

(ii) *Horizontal or Vertical*. While the former requires more floor space and less head space, the latter requires less floor space and more head space. Modern circulation cleaning methods have made very large vertical storage tanks practical.

(iii) *Rectangular, Cylindrical or Oval*. Of these, the first suffers

*The term 'processed' is generally used in a wide sense in dairying, and includes pasteurization, homogenization, evaporation, drying, etc. It is desirable to use a specific term when only one process is meant.

from the disadvantage of having dead corners during agitation, while the other two do not.

(iv) *Built for gravity flow, air-pressure or vacuum operation.* The first is the most common. However, air pressure is sometimes used to evacuate the product. This requires special construction of the storage tank for greater strength than necessary for normal operations under gravity flow (i.e. atmospheric pressure).

(d) *Location.* In one system, the storage tanks are located on an upper floor. The milk is pumped from the receiving room to the floor above. It then flows by gravity to the pre-heater, filter or clarifier, pasteurizer, cooler and bottling machine. In another system, the milk is pumped from the storage tanks through a pre-heater and filter into the pasteurizer. Thence it may flow by gravity to the cooler, or it may be pumped to the cooler while hot.

(e) *Parts of a Storage Tank.*

(i) Sight glass; (ii) light glass and lamp; (iii) ladder; (iv) man-hole; (v) agitator; (vi) outlet valve; (vii) inlet; (viii) air vent; (ix) safety valve; (x) legs; (xi) indicating thermometer; (xii) volume-meter.

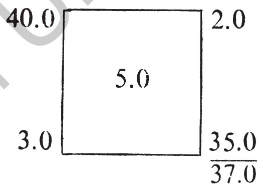
V. *Standardization*

(a) *Definition.* Standardization of milk refers to the adjustment, i.e. raising or lowering, of the fat and/or solids-not-fat percentages of milk to a desired value, so as to conform to the legal or other requirements prescribed.

(b) *Procedure.* Milk is standardized by the addition of milk or cream with a higher or lower fat percentage than that of the material to be standardized; sometimes the addition of skim milk will do To solve the problem, it is necessary to find the relative amounts of the original material and the standardizing material to be mixed together to give a product with the desired fat content. Once these relative amounts/proportions have been determined, it is easy to calculate the exact amount of each which must be mixed together to give a certain weight of the finished product or the exact amount of standardizing material needed to use up a given weight of milk or cream A simple scheme, the Pearson's Square, can be used to calculate the relative quantities of the materials involved in a standardization problem. It should be remembered that all measurements based on these calculations are by weight and not by volume.

The Pearson's Square method is as follows: draw a square and place in the centre of it the fat percentage desired. Place at the left-hand corners of the square the fat percentage of the materials to be mixed. Next, subtract the number in the centre from the larger number at the left-hand side of the square and place the remainder at the diagonally opposite right-hand corner. Subtract the smaller number on the left-hand side from the number in the centre and place the remainder at the diagonally opposite right-hand corner. The numbers on the right-hand side now represent the number of parts of each of the original materials that must be blended to make a product with a fat test given by the number in the middle of the square. The number at the upper right corner refers to the parts of material whose fat test was placed at the upper left corner, and the number at the lower right corner refers to the parts of material whose fat test was placed at the lower left corner. If the numbers on the right are added, the sum obtained will represent the parts of the finished product, with the fat test given by the number obtained in the middle of the square.

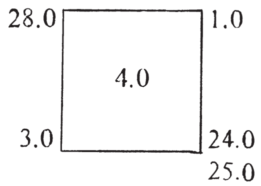
Problem I. How many parts by weight of 40% cream and 3% milk must be mixed to make milk testing 5% fat?
Solution.



Hence, 2.0 parts of 40% cream when mixed with 35 parts of 3.0% milk will give 37 parts of 5% milk. *Ans.*

Problem II. How many kg each of 28% cream and 3% milk will be required to make 500 kg of a mixture testing 4% fat?

Solution.



$1.0 : 25.0 = C : 500$, where C is cream required in kg

or $\frac{1}{25} = \frac{C}{500}$ or $C = \frac{500}{25} = 20$ kg *Ans.*

Milk (3%) = 500 − 20 = 480 kg *Ans.*

Proof.

500 kg of 4% milk contains $\frac{500 \times 4}{100} = 20$ kg fat

20 kg of 28% cream contains $\frac{20 \times 28}{100} = 5.6$ kg fat

480 kg of 3% milk contains $\frac{480 \times 3}{100} = 14.4$ kg fat

14.4 + 5.6 = 20 kg

VI. *Pasteurization*

A. *History*. The term pasteurization has been coined after the name of Louis Pasteur of France, who in 1860–4 demonstrated that heating wine at a temperature between 122 to 140°F (50 to 60°C) killed the spoilage organisms and helped in its preservation. The application of this process gave rise to the new term 'Pasteurization', which soon became current in technical language. Although Louis Pasteur pioneered studies on heat-treatment for preservation, pasteurization of milk was first attributed to Dr Soxhlet of Germany in 1886.

B. *Definition*. The term pasteurization, as applied to market milk today, refers to the process of heating every particle of milk to at least 63°C* (145°F) for 30 minutes, or 72°C (161°F) for 15 seconds (or to any temperature-time combination which is equally efficient), in approved and properly operated equipment. After pasteurization, the milk is immediately cooled to 5°C (41°F) or below.

C. *Object* (Purpose).

(a) To render milk safe for human consumption by destruction of cent per cent pathogenic micro-organisms;

(b) to improve the keeping quality of milk by destruction of almost all spoilage organisms (85 to 99 per cent).

*While converting Fahrenheit into Centigrade, the latter has been rounded off throughout this book so as to avoid fractions (as per the latest thinking in ISI).

D. *Need.* As it is difficult to exercise strict supervision over all milk supplies, it becomes necessary to pasteurize milk so as to make it safe for human consumption. Any impairment of nutritive value is of the slightest extent.

E. *Objections.*

(a) Pasteurization encourages slackening of efforts for sanitary milk production;

(b) it may be used to mask low-quality milk;

(c) it diminishes *significantly* the nutritive value of milk;

(d) it reduces the 'cream line' or 'cream volume';

(e) pasteurized milk will not clot with rennet;

(f) pasteurization may be carelessly done; it gives a false sense of security;

(g) it fails to destroy bacterial toxins in milk;

(h) in India pasteurization is not necessary, as milk is invariably boiled on receipt by the consumer.

F. *Formulation of standards.* The following considerations were involved in the formulation of the standards of pasteurization:

(a) *Bacterial destruction.* Cent per cent for pathogens. *Mycobacterium tuberculosis*, being considered the most heat-resistant among pathogens, was chosen as the index organism for pasteurization. Any heat treatment (i.e. temperature-time combination), which killed T.B. germs, also destroyed all other pathogens in milk.

(b) *Cream line reduction.* The creamline or cream volume is reduced progressively with increase in the temperature-time of heating. (The consumer judges the quality of milk on the basis of the creamline.)

(c) *Phosphatase inactivation.* The complete destruction of phosphatase by pasteurization. (The phosphatase test is used to detect inadequate pasteurization.)

Thus the standards of pasteurization were such as to ensure: (a) complete destruction of pathogens; (b) negative phosphatase test; and (c) least damage to the cream line. As T.B. germs are destroyed by a heat-treatment slightly lower than that for phosphatase inactivation, pasteurization is carried out at a heat-treatment temperature *above* that for phosphatase inactivation and yet *below* that for cream line reduction, as shown in Table 1.27.

Table 1.27

Pasteurization requirements

Particulars	30 minutes	15 seconds
To kill T.B. germs	138°F/58.9°C	158°F/70°C
To inactivate phosphatase	142°F/61.1°C	160°F/71.1°C
Pasteurization requirements	143°F/61.7°C*	161°F/71.7°C
Creamline reduced	144°F/62.2°C	162°F/72.2°C

G. *Salient remarks.*

(a) Although pasteurization is now considered a health measure, it is actually a commercial expedient;

(b) pasteurization is neither a cure-all, nor is it fool-proof;

(c) post-pasteurization should be avoided.

H. *Pasteurizing process and equipment.*

(aa) *Introduction.* The equipment for pasteurization and the needs or specifications for adequate heat-treatment of milk have been developed simultaneously. To ensure proper pasteurization with a minimum amount of equipment and controls and the least risk, holding methods or batch processes were developed. As operations grew, it became evident that higher temperatures would reduce the necessary holding time for pasteurization; this would result in a continuous operation, and with more compact equipment less plant space would be necessary.

(bb) *Principles of heat-exchange.* The general principles for efficient heat-exchange are:

(i) Rapid movement of film of fluids on both sides of the heat transfer surface;

(ii) thorough and certain mixing of this film with the body of the fluids;

(iii) use of the counterflow principle.

(iv) as great a temperature difference as possible, consistent with accurate temperature control and prevention of any deleterious effect on the product treated;

(v) the use of the least number of intermediate fluids as possible;

(vi) as thin a sheet of heat-transfer wall as possible, consistent with proper mechanical strength;

(vii) use of metals of good conductivity.

*145°F/62.8°C (since 1956).

(cc) *Considerations involved in the heating of milk.*

(i) The problem in heating milk is to obtain quick heat transfer without imparting a cooked flavour (and also impairing the creaming properties of milk).

(ii) The rate of heat transfer is mainly dependent on: the temperature gradient, renewal of surface films, thermal conductivity of the heat-transfer wall, heat-transfer area, etc.

(iii) The temperature gradient is initially quite high, but becomes smaller as milk approaches the desired pasteurization temperature. (A gradient which is too high at the end may injure the flavour and creaming properties of milk.)

(iv) Efficient renewal of surface films hastens heat transfer, so that a high temperature gradient is unnecessary. (Renewal of surface films involves flow or agitation of two liquids, viz. milk and water. Agitation of milk is limited, as at high temperatures it may cause partial 'homogenization' of fat globules; while that of water is limited only by considerations of design, cost of pumping, etc.)

(v) In case of two liquids, viz. milk and water, the principle of a counter-current flow is invariably used. (Only by a counter-current flow can milk fully attain the temperature of the heating/ cooling medium; if the two are co-current, an intermediate temperature will result.)

(vi) Efficiency of renewal of surface films can eliminate use of metals of high thermal conductivity.

(vii) Provision of as large a heat-transfer area as possible contributes towards rapid heat transfer. For this purpose, the plates of the heat-exchanger are corrugated in various ways to increase their surface area. (The corrugations also give high efficiency turbulent flow.)

(viii) The heating medium is almost invariably hot water; sometimes steam under partial vacuum is also used. The hot water is circulated under pump pressure.

(dd) *Methods.*

(a) *In-the-bottle pasteurization.* Bottles filled with raw milk and tightly sealed with special caps are held at 63–66°C (145–150°F) for 30 minutes. Then the bottles pass through water sprays of decreasing temperatures which cool both the product and the bottle.

Advantage. Prevents possibility of post-pasteurization contamination.

Disadvantages. (i) Transfers heat very slowly; (ii) there is greater risk of bottle breakage; (iii) oversized bottles have to be used, to allow for milk expansion during heating; (iv) special types of water-tight caps have to be used. This method is at present outdated, although in-the-bottle sterilization of milk is widely prevalent.

(b) *Batch/holding pasteurization.* This is also called the Low-Temperature-Long-Time (LTLT) method. The milk is heated to 63°C/145°F for 30 minutes and promptly cooled to 5°C or below. In this system, heating is done indirectly; the heat moves through a metal wall into the product for heating, and out of the product for cooling. The pasteurizer may be of three types:

(i) *Water-jacketed vat.* This is double-walled around the sides and bottom in which hot water or steam under partial vacuum circulates for heating, and cold water for cooling. The outer wall (lining) is usually insulated to reduce heat loss. The heat-exchange takes place through the wall of the inner lining. The difference between the temperature of the heating water and the milk is kept to a minimum. The milk is agitated by slowly moving (revolving) paddles/propellors. When heating, the vat cover is left open for escape of off-flavours; and when holding, the cover is closed. During the holding period, an air space/foam heater (steam or electrically heated) prevents surface cooling of milk.

Advantage. Flexibility in use. (It is also known as a multipurpose or multi-process vat.)

(ii) *Water-spray type.* A film of water is sprayed from a perforated pipe over the surface of the tank holding the product. The product is agitated as above. A rapidly moving continuous film of water provides rapid heat transfer.

Advantage. The same as above.

(iii) *Coil-vat type.* The heating/cooling medium is pumped through a coil placed in either a horizontal or vertical position, while the coil is turned through the product. The turning coil agitates the product (but additional agitation may be necessary).

Disadvantage. Coils are difficult to clean, which accounts for the decline in their use.

Note. (i) As vat heating/cooling is rather slow and involves too much agitation, causing churning and impairment of creaming properties, this operation can be efficiently carried out by Plate or Tubular Heat Exchangers.

(ii) With the vat holding system, a continuous flow of milk can be obtained with multiple vat installation; however, this may encourage the growth of thermophilic organisms over long periods.

(c) *High Temperature Short Time (HTST) pasteurization.*

1. *Introduction.* This was first developed by A. P. V. Co. in the United Kingdom in 1922. It is the modern method of pasteurizing milk and is invariably used where large volumes of milk are handled. The HTST pasteurizer gives a continuous flow of milk which is heated to 72°C (161°F) for 15 seconds and promptly cooled to 5°C or below.

2. *Advantages.* (i) Capacity to heat-treat milk quickly and adequately, while maintaining rigid quality control over both the raw and finished product; (ii) less floor space required; (iii) lower initial cost; (iv) milk packaging can start as soon as pasteurization begins, thus permitting more efficient use of labour for packaging and distribution; (v) easily cleaned and sanitized (system adapts itself well to CIP-cleaning); (vi) lower operating cost (due to fullest use of regeneration): (vii) pasteurizing capacity can be increased at nominal cost; (viii) reduced milk losses; (ix) development of thermophiles not a problem; (x) the process can be interrupted and quickly restarted; (xi) automatic precision controls ensure positive pasteurization.

3. *Disadvantages.* (i) The system is not well-adapted to handling small quantities of several liquid milk products; (ii) gaskets require constant attention for possible damage and lack of sanitation; (iii) complete drainage is not possible (without losses exceeding those from the holder system); (iv) margins of safety in product sanitary control are so narrow that automatic control precision instruments are required in its operation; (v) pasteurization efficiency of high-thermoduric count raw milk is not as great as it is when the holder system is used; (vi) greater accumulation of milk-stone in the heating section (due to higher temperature of heating)

4. *Milk flow.* The following steps or stages are involved as milk passes through the HTST pasteurization system: balance tank; pump; regenerative heating; holding; regenerative cooling; and cooling by chill water or brine. An arrangement for incoropr-

ation of the filter/clarifier, homogenizer, etc., in the circuit is also made when desired. There is some variation in the use or order of these steps in different milk processing plants.

5. *Functions of the important parts.*

(i) *Float-Controlled Balance Tank* (*FCBT*). Maintains a constant head of milk for feeding the raw milk pump; also receives any sub-temperature milk diverted by FDV.

(ii) *Pump.* Either a rotary positive pump between the regenerator and heater (USA), or a centrifugal pump with a flow control device to ensure constant output, after FCBT (UK and Europe) is used.

(iii) *Plates.* The Plate Heat Exchanger (also called Paraflow) is commonly used in the HTST system, especially for heating to temperatures which are below the boiling point of milk. The plate heat exchanger is a compact, simple, easily cleaned and inspected unit. Its plates may be used for heating, cooling, regeneration and holding. These plates are supported in a press between a terminal block in each heating and cooling section. The heat moves from a warm to a cold medium through stainless steel plates. A space of approximately 3 mm. is maintained between the plates by a non-absorbent rubber gasket or seal which can be vulcanized to them. The plates are numbered and must be properly assembled. They are tightened into place, and are so designed as to provide a uniform but not excessively turbulent flow of products with rapid heat transfer. Raised sections (corrugations) on the plates in the form of knobs, diamonds and channels, help provide the turbulent action required. Greater capacity is secured by adding more plates. Ports are provided in appropriate places, both at the top and bottom of the plates, to permit both the product and the heating/cooling medium to flow without mixing.

(iv) *Regeneration* (*Heating*). The (raw) cold incoming milk is partially and indirectly heated by the hot outgoing milk (milk-to-milk regeneration). This adds to the economy of the HTST process, as the incoming milk requires less heating by hot water to raise its temperature for holding.

(v) *Filter.* Variously shaped filter units to connect directly to the HTST system are placed after the pre-heater or regenerative (heating) section. These units, using 40–90 mesh cloth, are usually cylindrical in shape. Usually two filters are attached but they are used one at a time. This permits continuous operation, the flow being switched from one to the other while replacing a filter.

(vi) *Holding.* The holding tube or plate ensures that the milk is held for a specified time, not less than 15 seconds, at the pasteurization temperature of 72°C (161°F) or more.

(vii) *Flow diversion valve (FDV).* This routes the milk after heat treatment. If the milk has been properly pasteurized, it flows forward through the unit; that which is unpasteurized (i.e., in which the temperature does not reach the legal limit) is automatically diverted back to the FCBT for reprocessing. It is usually operated by air pressure working against a strong spring. Should the temperature fall, air pressure is released and the valve snaps shut immediately. When the temperature is regained, air pressure builds up and the valve opens to forward flow. The system is so arranged that any failure of air or electricity moves the valve in the diverted position.

Note. The flow of unpasteurized milk can also be stopped with a 'pump stop', which automatically stops the milk-pump motion if the product temperature drops below the desired level. When the proper temperature is reached, the pump stop restarts the operation and allows the flow of milk to continue.

(viii) *Regeneration (cooling).* The pasteurized hot outgoing milk is partially and indirectly cooled by the incoming cold milk (milk-to-milk regeneration). This again adds to the economy of the HTST process. In fact, when pre-cooled (raw) milk is received, the high degree of regeneration (72 to 85%) allows water cooling to be dispensed with entirely.

(ix) *Control panel.* Contains instruments, controls, FDV-mechanism and holding system, all centralized in one moisture proof panel. The lower half of the panel forms an air-insulated chamber which carries the holding tube.

(x) *Hot water set.* Circulates hot water through the heating section of the machine to maintain the correct milk temperature within very fine limits.

(xi) *Automatic control devices.* These include:

Steam pressure controller. Maintains a constant hot water temperature for heating milk accurately to the required pasteurization temperature. (Acts as a reducing valve in the steam supply line, so as to give a constant steam pressure.)

Water temperature controller. Regulates the amount of steam entering the hot water circulating system.

Milk temperature recorder. Records the temperature of milk leaving the holding tube/plate. This is an electric contact instrument that operates either a FDV or a milk pump, automatically preventing milk from leaving the holding section at sub legal temperatures. Both the frequency and duration of the flow diversion and the temperature of milk leaving the holder are recorded on the thermograph (recording chart) by means of two separate pens. (The 'check thermometer' is placed near the milk temperature recorder.)

6. *Pressure in the system.* The normal pressures maintained in the HTST system are:

Pasteurized milk	15 psi
Raw milk	14 psi
Heating/cooling medium	12 to 13 psi

7. *Holding time test.* The holding time of a HTST pasteurizer is the flow time of the fastest particle of milk at a prescribed temperature through the holding section. The holding time is calculated between the points at which the heated milk leaves the heating section and reaches the FDV. The efficiency of pasteurization in the HTST system depends as much on the correct maintenance of temperature as on the holding time. Hence the latter should be checked periodically. Several methods are used for determination of the holding time, viz. the electrical conductivity method (of a salt solution); the dye injection method; the electronic timer method; etc.

(d) *Electric pasteurization.* (See *Fluid Milk Industry* by Henderson (1971)).

(e) *Vacuum pasteurization* (*Vacreation*). This refers to pasteurization of milk/cream under reduced pressure by direct steam. The process was first developed in New Zealand by M/s Murray Deodorizers Ltd. who called the equipment a 'Vacreator' and the process 'Vacreation'. It was designed to remove feed and other volatile flavours from cream, and to pasteurize it for buttermaking.

The vacreator consists of three stainless steel chambers connected to one another for steam heating and vacuum treatment with continuous product flow. The product, in the form of fine droplets, enters the first chamber of the vacreator where pasteurization occurs. The chamber is operated under a vacuum of 5 inches Hg which maintains a temperature of 90 to 95°C, while steam, fed from the top, falls by gravity to the bottom of the chamber. Then the product and some free steam are moved from the bottom of the first chamber to the top of the second one. The temperature of the second chamber is maintained at 71 to 82°C under a vacuum of 15 to 20 inches Hg. A portion of the steam previously added is removed, and the product moves down through the chamber. Some of the tainting substances and off-flavours are removed by heat and vacuum treatment. The product then moves on to the third chamber at 43°C by maintaining a vacuum of 26 to 28 inches Hg, and here more water and off-flavours are removed. A multi-stage centrifugal pump removes the product from the third chamber. Altogether, it takes the product about 10 seconds to move continuously through the unit. (Steam of uniform pressure, normally ensured by a uniform pressure reducing and regulating valve, should be provided. It must not contain any boiler compounds which may contaminate the product.)

(f) *Stassanization.* This method of pasteurization is carried out in a tubular heat exchanger consisting of three concentric tubes. It was invented in France by Henri Stassano and is used to a considerable extent in French, Danish, Italian and other milk plants. The principle of its operation is the heating of milk to the desired temperature by passing it between two water-heated pipes through the narrow space of 0.6 to 0.8 mm. The milk is heated to about 74°C (165°F) for 7 seconds and then promptly cooled as usual.

(g) *Ultra-high temperature pasteurization.* Ultra-high temperature (UHT) pasteurization was developed in the 1950s. This usually encompasses temperature-time combinations of 135 to 150°C (275 to 302°F) for no-hold (a fraction of a second). The success of UHT heat-treatment of milk depends on immediate aseptic packaging.

(h) *Flash pasteurization.* In earlier days, this term was used for what is today called HTST.

(j) *Uperization.* This is itself a shortened form of the word 'Ultra-pasteurization', which has been developed in Switzerland. In this process milk is heated with direct steam up to 150°C (302°F) for a fraction of a second. The process is continuous.

The method of manufacture of uperized milk is as follows:

high quality raw milk is immediately clarified on receipt, then chilled and stored in tanks. In the first part of the uperization process, the milk is forewarmed to 50°C and de-aerated to remove most of the dissolved oxygen and volatile off-flavours by vacuum treatment. In the second part, the milk is first pre-heated to about 80–90°C and then heated in the uperization chamber with high pressure steam to around 150°C for $\frac{1}{3}$ to $\frac{3}{4}$ second. After this heating, the product moves into an expansion chamber at near atmospheric pressure, thereby forcing some evaporation of moisture. The product is then moved to a cooler and then into storage.

The advantages claimed for uperized milk are: (i) long keeping quality; (ii) removal of feed and other volatile off-flavours; (iii) appreciable homogenization effect; (iv) reduction in acidity; (v) efficient destruction of micro-organisms; (vi) effect of uperization on nutritive value and flavour no greater than that of pasteurization.

J. *Alternatives to pasteurization.* Various types of treatment have been proposed from time to time as alternatives to pasteurization. These include: (a) the Hofius process; (b) electronic heating; (c) ultra-violet irradiation; (d) ultra-sonic vibration, etc.

VII. *Homogenization.* A considerable proportion of market milk pasteurized in developed dairying countries is now homogenized as well. The homogenizer may be located immediately after regenerative heating, or between final heating and holding, or after FDV and before regenerative cooling. (See 2.2 for more information.)

VIII. *Bottling/Packaging*

A. *Introduction.* The pasteurized and cooled milk is promptly bottled/packaged so as to serve the dual purpose of: (a) protecting the milk against contamination, loss, damage or degradation (due to: micro-organisms or insects; exposure to heat, light, moisture or oxygen; spillage, evaporation or pilferage), and (b) helping in the sale and distribution of the milk (by packaging it in an easy-to-carry-and-open, sufficiently strong and leak-proof, non-tainting container).

B. *Bottling and Capping*

(aa) *Bottles.* The glass bottle is still universally used. It is usually transparent, although in some countries brown bottles have been tried. (Brown bottles prevent light-induced off-flavours in milk; but on the other hand, the product is not visible for inspection.) The glass bottle is generally round, but may also be square in shape (as in the USA); the latter is considered to be more economical of storage space. Light-weight yet sturdy, the glass bottle is best since it decreases the pay-load of retail vehicles.

Bottles should be examined for their colour, capacity and strength, before use. The tests (prescribed in *IS:1392*, 1959) include the following: (i) colour and appearance; (ii) shape; (iii) dimensions (height and neck diameter); (iv) weight; (v) serrations; (vi) minimum wall thickness; (vii) nominal capacity; (viii) strength or durability (these consist of thermal shock test, internal pressure test, impact test, polariscope examination, etc.).

In plants of small capacity, milk may be bottled with hand fillers operated manually with a lever and capable of filling 4 to 12 bottles at a time. The caps are then usually applied with a hand capper. In larger plants, automatic, continuous, mechanical bottle fillers and cappers are used. These are broadly of two types, viz., gravity fillers and vacuum fillers. In the former, the milk flows by gravity into the bottles as they are pressed against the filling valves; in the latter, the bottles are filled by creating a vacuum within them. The milk from the cooler usually goes directly into the bowl of the bottle-filling machine, the connecting pipe being equipped with a valve that regulates the flow. Bottle washing operations are so timed in relation to the processing of milk that washed and sanitized bottles arrive at the filler as needed for immediate bottling.

There are two principles in filling, viz. level filling and quantity filling. Level filling is quicker and more common; most bottle fillers are designed to fill milk bottles to a pre-determined level; however, a constant low temperature of milk at the time of filling, should be maintained. Quantity filling, although more accurate since it is not affected by either temperature or foam, is slower and hence seldom used.

(bb) *Bottling* (*Bottle filling*)

(a) *Gravity fillers.* These consist mainly of six different parts, viz., the drive, bowl, filler valves, carrier, capper and star wheels. The circular bowl receives the milk to be bottled. The level of milk is kept constant by a float valve on the inlet pipe. Filling valves are attached radially to the bottom of the bowl. Bottles are fed by hand or directly from the bottle washer by a conveyor. They are mechanically centred into lifters which are located directly under the filling valves and which revolve with them. These lifters rise automatically as the filler revolves and the mouth of the bottle is forced against a tightly fitting rubber valve. The rising bottle pushes up the valve and the milk flows down into the bottle. As the filling valve almost completes a revolution, the lifter on which the bottle is carried is lowered automatically and the valve closes and remains closed until the next bottle opens it. The filled bottle is then transferred to a capper where it is automatically sealed and the lifter, now in the lowered position, is ready to receive another empty bottle for filling. While the bottle is being filled, the air which is displaced by the incoming milk escapes through a vent tube, which extends from the bottom of the valve sleeve to a point above the milk level in the bowl. The height of the bowl-tank is adjusted by the operator to suit the size of each bottle that is to be filled. Bottles are automatically discharged from the capper onto a conveyor that delivers them to an accumulating table, from where they may be loaded into crates manually or mechanically.

Advantages: (i) relatively simple to operate; (ii) maintenance not too complicated; (iii) easily and swiftly cleaned.

Disadvantages: (i) slow filling and hence limited capacity; (ii) leakage losses high (due to badly sealed bottle, bottle with chipped mouth, faulty valve, etc.).

(b) *Vacuum fillers*. These may be either vacuum-assisted (single-bowl) or straightforward vacuum (double-bowl) types. In the former, the typical gravity bowl, which has open vent tubes and conventional gravity valves, is closed with an air-tight cover. In the latter, there is a rotary bowl and a float bowl. The float bowl is slightly below the level of the tops of the filling head. When the bottle is raised against the rubber ring on the filling head, a seal is formed and air inside the bottle is immediately drawn out through vertical vacuum pipes, and the milk is drawn from the float bowl through the milk pipes to the filling head and is released into the bottle. Foam is drawn off through the vacuum pipes into the vacuum tanks. Excess milk collecting in the vacuum tank automatically goes into the float bowl. Towards the end of the revolution of the filler, the lifters, on which the bottles are carried, are lowered, and the seal is broken. Any milk remaining in the milk pipe syphons back into the float bowl and that remaining in the vacuum line is drawn back into the vacuum tank.

Advantages: (i) rapid filling; (ii) will not fill a bottle with a chipped mouth or bad seal, thus saving milk; (iii) no milk drip through faulty valves.

Disadvantages: (i) maintenance complicated; (ii) relatively complicated to operate; (iii) cleaning more time-consuming.

(cc) *Caps and capping*. The capping machine is often incorporated into the filler, and in any case, its work must synchronize with it. The milk bottle cap or closure has three main functions: (i) to retain the milk within the bottle; (ii) to protect the pouring lip from contamination; and (iii) to seal the bottle against tampering. (In this case, tampering refers to the removal or replacement of milk from a bottle without this being evident from the appearance of either the bottle or the milk within it.)

The caps may be: (i) cardboard discs, impregnated with a moisture-proof layer (paraffin wax or polythene); (ii) aluminium foil caps; (iii) crown corks. The cardboard discs with separate hoods were the first to be introduced, but are not much used now. The aluminium foil cap is most commonly used. It is either pre-formed or formed-in-place, both types having their advantages and disadvantages. The foil may be 0.05 to 0.15 mm. thick and of 50 mm. width (see *IS:1705*, 1960). Crown corks are generally used for sterilized milk; they are made of lacquered tin plate, the inner surface of which is lined with water-proof paper/polythene, and are more expensive. (All types of caps or closures can be printed or embossed with names or trade marks and can be coloured for coding purposes.)

(dd) *Inspection of filled bottles*. Before being (manually) placed in crates, filled milk bottles should be inspected for dirt, etc. by rotating them as they are removed from the machine.

(ee *Decrating and recrating of bottles*. Removing dirty bottles from crates (decrating) and refilling them with bottles of pasteurized milk (recrating) are among the most back-breaking and labour-consuming operations in the dairy. Both decrating and recrating machines look the same. The decrator lifts the empty bottles by vacuum-operated rubber-grippers and rejects any that are damaged. The recrator lifts the filled bottles by compressed-air operated rubber-grippers. In decrating, the crates of empty bottles are at first correctly positioned before lifting, while in recrating, a special marshalling mechanism allows bottles from the filler to assemble in correctly positioned groups, ready to be picked up for transfer to the crates.

(ff) *Crate stacker.* This stacks crates containing filled bottles, thereby relieving labour of another back-breaking job.

C. *Packaging* (Also see Appendix I)

Although the glass milk bottle is still the traditional packaging medium for retail milk distribution, single-service paper/plastic containers are increasingly being adopted for the same purpose. A survey has shown that in some European countries they have captured two-thirds of the market. A beginning in this field has also lately been made in India. As far as milk packaging is concerned, paper is a carrier for a water-proof layer of either polyethylene or wax. The provision for 5 to 10 per cent of synthetic fibres is said not to influence the printing or folding capacity of paper, but rather to provide better wet strength. Dominated, in milk packaging, by polyolefines (such as polypropylene and polyethylenes), used singly or blended to offer a wide range of materials, plastics have superseded paper in recent times. The polyolefines of interest are coating grades for cartons, film grades for sachets and extrusion/blowing grades for bottles.

Cartons are commonly used for both bulk and retail sale. They are made of combinations of food grade paper and wax or plastics. The distribution advantages of cartons are: maximum space utilization in vehicles and storage, ability to carry attractive printing, and convenience for the purpose of stacking milk on super-market shelves. The carton systems in common use are: Perga (U.K.); Pure Pak (U.S.A.); Zupack, Blockpack (W. Germany); and Tetra Pak (Sweden). When filling the cartons, either preformed or pre-cut blanks may be used. Pre-formed cartons are supplied in a fully erect form ready for filling; in the pre-cut system the blanks are supplied in a knocked down shape and the final carton is set up, formed, filled and sealed on one machine.

Sachets are flexible water-proof bags. Since it is difficult to pour from sachets, they are usually equipped with a jug. The sachet systems in common use are: Polypack, Bertopack (Switzerland); Finnpack (Finland); Milk-Pack, Rotapack (W. Germany); and Prepac (France). Sachet filling of milk usually follows a form/fill/seal system. The sachets are formed from a reeled film over a shoulder and tube-forming sealer. Their size is changed simply by pushing a button without stopping the machine. They are filled by a time-regulated valve accurate within ±3 ml./litre. Ultra-violet light is used to sterilize the inside of the film.

D. *Glass Bottle vs Paper/Film Package*

The relative advantages and disadvantages of paper/film packaging of milk over bottling are given below:

Advantages: (i) light in weight, easy to handle and no danger of breakage; (ii) distribution costs lower (occupies less space, lower pay-load due to light weight, no collection of empties); (iii) bottle-washing costs eliminated (saving in equipment, detergents, steam, etc.); (iv) tamper-proof; (v) effective sales message can be printed; (vi) less noisy (during filling, sealing and transportation); (vii) no exposure to sunlight; (viii) filling machinery compact and occupies much less space; (ix) no container deposit needed.

Disadvantages. (i) Costs higher per unit milk distributed; (ii) product not visible; (iii) difficult to remove cream; (iv) inspection of milk (for sediment) not possible; (v) regular supply of special paper/film essential; (vi) not so easy to open; and (vii) some cases of leakage may occur.

IX. *Storage*. In any milk plant, it is necessary to provide refrigerated rooms where milk can be stored until delivery. The temperature of milk storage rooms should be 5°C or below so as to check bacterial growth.

1.18 Distribution*

(a) *Introduction*. Distribution of milk is the last or final stage of the market milk industry. Others are preparatory to placing the product into the hands of the consumer. The quality of the

*All developed countries today invariably adopt the bottled/packaged milk distribution system. Nevertheless, unpacked (i.e., loose) milk distribution is quite prevalent in developing countries, as in India. While the disorganized sector of the Indian dairy industry follows the loose milk distribution system, the organized sector pursues the pattern of developed countries. A notable exception is the Mother Dairy, Delhi, which has adopted the NDDB-devised bulk-milk-vending system since 1974.

This dairy has set up milk-vending booths in various parts of the city. In each booth there is installed an NDDB-designed coin(token)-operated milk vending machine, popularly known as the 'push-button mini-dairy'. The milk holding capacity of these machines varies from 1000 to 1300 litres each. The consumer is expected to bring his/her own container large enough to hold the milk. He/she is expected to go to the concessionaire and exchange product alone will not assure its wide distribution, which should be planned and executed intelligently.

Distribution facilities consist of: (i) the physical equipment and personnel required for transporting the products from the milk storage rooms to the consumer/retailer; (ii) sales promotion personnel; and (iii) advertising.

A successful distribution programme requires: (i) a product of high quality; (ii) an attractive package; (iii) neat and courteous route salesmen; (iv) delivery equipment of pleasing appearance; (v) efficient use of men and equipment; (vi) effective advertising.

(b) *Route organization.* This varies with the size and the type of business. In a small plant, the same drivers and trucks may deliver both wholesale and retail goods. In larger organizations, wholesale and retail distribution are usually handled by separate personnel and equipment. Wholesale routes handle larger volumes and have fewer stops than do retail routes. For economical operation, the truck should be utilized for a maximum number of hours per day for milk distribution.

(c) *Payment of route salesmen.* Three different methods are in use: (i) *Flat salary.* Gives no incentive to sell more products, secure new customers, etc.; (ii) *Salary plus commission.* Most satisfactory; (iii) *Straight commission.* Used when the driver owns the route and equipment.

(d) *Checking out the routes.* Different systems may be used for loading the trucks in checking out the routes. The trucks must be loaded rapidly so that the drivers are not delayed at loading stations. The principal systems are: (i) loading directly from the storage rooms through one or more doors; (ii) using a long loading platform with conveyors from the milk-storage rooms; (iii) loading platform-trolleys in the storage room with orders for the different routes. The platform trolleys are then wheeled onto the loading platform and finally loaded into the

money for metal tokens. The container is to be placed under the tap. On inserting the token into the slot the button lights up. On pressing the button, the first half litre of milk flows out. The process is repeated to get the second instalment of milk by inserting another token, and so on. The dairy claims that this method enables it to pay more to the milk producers (on account of the savings effected in the cost of packaged milk distribution), and yet operate the dairy on a 'no-profit-and-no-loss' basis. The results of this unique experiment are awaited with great interest.

delivery trucks. (The first two systems are suitable for medium size and large plants, the third for small ones.)

(e) *Checking in the routes.* This consists of verifying the driver's count of empty bottles and unsold goods and conveying the bottles to the washers or to storage. The driver usually places the bottles on the platform, conveyor or platform-trolley.

(f) *Sales outlets.* These include (for both wholesale and retail sales) the following: (i) home delivery; (ii) milk booths or distribution depots/bars; (iii) stores; (iv) soda fountains; (v) coin vending machines; (vi) automatic dispensers; (vii) factories, hospitals, jails, restaurants, schools, etc.; (viii) lunch counters.

(g) *Anticipating daily demand.* This is usually based on past experience, taking into consideration holidays, fairs and festivals, special events, etc.

(h) *Frequency of distribution.* Due to highly changeable temperatures during most seasons and the lack of refrigeration facilities at the average customer's home in India the milk has to be distributed twice daily, viz., morning and evening. In cold countries, one-time delivery is usual.

(j) *Utilization of returned milk.* Unsold milk presents a problem of economic disposal. Under tropical conditions, as in India, the returned milk should not be sent again for sale as liquid milk since exposure to high temperatures during its inward and outward journeys subject it to quality deterioration and hence may cause consumer complaints. The unsold milk can be given for separation or utilized for preparation of dahi, etc.

(k) *Systems of collection for the payment of milk.* These are credit, cash or advance payment (coupon/monthly card). Their relative merits and demerits are given in Table 1.28.

TABLE 1.28

Comparison of different collection-systems for the payment of milk

System	Merits	Demerits
Credit	(i) Attractive to customers (as no immediate payment and locking up of money) (ii) Rapid deliveries (iii) Accounting is easy	(i) Losses through bad accounts (ii) Needs special check on amount delivered

System	Merits	Demerits
Cash	(i) No losses through bad accounts as money collected on the spot	(i) Slows down deliveries as some customers may not bring correct change (ii) Less attractive to customers (iii) Counterfeit coins are a problem (iv) Carrying of large amounts of cash may be risky (for dairy staff)
Coupons	(i) No losses through bad accounts (ii) Curbs corruption (especially on the part of dairy staff)	(i) Slows down deliveries (ii) Increases the sale price of milk (iii) Less attractive to customers (as money locked up) (iv) Final accounting is cumbersome (v) Special check needed for misuse of coupons (lost or stolen from rightful owner) (vi) Chances of fraudulent printing of coupons

1.19 Cleaning and Sanitization of Dairy Equipment

A. *Definitions*

Cleaning or washing of dairy equipment implies the removal of 'soil' from the surface of each machine.

Sanitization (also referred to as sterilization) implies the destruction of all pathogenic and almost all non-pathogenic micro-organisms from equipment surface.

Note. 'Soil' consists primarily of milk or milk product residues which may be more or less modified by processing treatment, or by interaction with water or cleaning materials previously used, or by dust, dirt or other foreign matter. (Soil may be one or more of the following: liquid milk films, air-dried films, heat-precipitated films, heat-hardened films, milk-stone and miscellaneous foreign matter.)

Detergents or cleaning/washing compounds are substances capable of assisting cleaning.

Sanitizers are substances capable of destroying all pathogenic and almost all non-pathogenic micro-organisms.

Milk-stone is an accumulation of dried milk solids and salts from hard water and washing solutions. It consists largely of calcium phosphate, milk protein, precipitated, coagulated and baked-on by heat, and insoluble calcium-salts from water and washing solutions. It has the following approximate composition:

Moisture	2.7 to 8.7%
Fat	3.6 to 17.7%
Protein	4.4 to 43.8%
Ash	42.0 to 67.3%

B. *Importance*

All dairy equipment should be properly cleaned and sanitized as milk provides an excellent medium for the growth of micro-organisms. At the same time, detergents and sanitizers used for cleaning and sanitization should be so selected as not to affect the material of the equipment.

Cleaning and sanitization are complementary processes; either of them alone will not achieve the desired result, which is to leave the surfaces as free as possible from milk residues and viable organisms.

C. *Detergents*

(a) Detergents should have the following desirable properties: (i) wetting and penetrating power; (ii) emulsifying power; (iii) saponifying power; (iv) deflocculating power; (v) sequestering and chelating power; (vi) quick and complete solubility; (vii) should be non-corrosive to metal surfaces; (viii) free rinsing; (ix) economical; (x) stability during storage; (xi) should be mild on hands; (xii) should possess germicidal action.

Note. No single detergent possesses all the above properties. Hence two or more detergents are compounded for different operations so as to combine cleaning efficiency with safety.

(b) Dairy detergents may be broadly classified into 4 groups:

(i) *Alkalis.* Sodium hydroxide (caustic soda), sodium carbonate (washing soda), sodium phosphates, sodium bicarbonate/sesquicarbonate, sodium silicate/sulphite (as inhibitors), etc.

Strong alkalis are used to saponify fat and weak alkalis to dissolve protein.

(ii) *Acids.* (Mild) Phosphoric, tartaric, citric, gluconic and hydroacetylic; (Strong) Nitric. Mild acids are used for milk-stone removal; nitric acid may be used in not more than 1 per cent concentration for stainless steel surfaces.

(iii) *Polyphosphates and chelating chemicals.* These are used together with acids or alkalis. Examples: Tetraphosphate, hexametaphosphate, tripolyphosphate, pyrophosphate, etc.

(iv) *Surface-active/wetting agents.* These are either used alone or in conjunction with acids or alkalis. Examples: Teepol, Acinol-N, Idet-10, common soaps, etc.

Note. By careful choice from the above materials it is possible to prepare mixtures possessing the desired degree of cleaning efficiency.

D. *Sanitizers.*

These should have the following desirable properties: (i) non-toxic (ii) quick acting; (iii) relatively non-corrosive to hands and equipment; (iv) easily and quickly applied; (v) relatively inexpensive. The commonly used dairy sanitizers are: steam, hot water, and chemicals (chlorine compounds, iodophor and quaternary ammonium compounds). The method of chemical sanitization broadly consists of: flushing, spraying, brushing, fogging and submersion.

E. *Cleaning and Sanitizing Procedure*

I. *Principles.* In the selection of any particular detergent, consideration should be given to: type of soil, quality of water supply, material of surface and the equipment to be cleaned, and method of cleaning, viz., soaking, brushing, spraying and/or recirculation. Detergents are invariably used as an aqueous solution. In the selection of dairy sanitizers, the following considerations are kept in mind: (a) *High temperature sanitizing.* Main advantages are penetrating ability and quick drying of the equipment. Heat is the most reliable sanitizer, especially when both temperature and time are controlled. Thus effective sanitization can be done by steam (15 psi for 5 minutes or 0 psi for 15 minutes) or scalding water (90–95°C for 10 minutes). (b) *Low temperature* *sanitizing*. Main advantages are: (i) permits sanitizing immediately before equipment is used (when hot equipment will be injurious to the quality of milk or milk products); (ii) avoids excessive strain on equipment (such as ice-cream freezers); and (iii) permits flushing out of equipment immediately before use, thereby removing any possible dust that may have entered. Generally, chlorine solution at 15–20°C containing 150 to 200 ppm available chlorine, is used for a contact time of 1 to 2 minutes.

The usual procedure for cleaning and sanitization of major items of dairy equipment should consist of:

(i) *Draining*, to remove any residual loose milk and any other matter.

(ii) *Pre-rinsing*, with cold or tepid water, to remove as much milk residue and other matter as possible.

(iii) *Warm to hot detergent washing* with detergent solution of 0.15 to 0.60 per cent alkalinity, to remove the remaining milk-solids.

(iv) *Hot water rinsing*, to remove traces of detergents.

(v) *Sanitizing*, to destroy all pathogens and almost all non-pathogens. (Usually also done just before using the equipment.)

(vi) *Draining and drying*, to help prevent bacterial growth and corrosion. (Drying readily accomplished by heat and ventilation; never use a cloth or towel of any kind. Drying not necessary if equipment is to be immediately refilled with a dairy product.)

The selection and precautions in the use of detergents and sanitizers for different surface-materials of dairy equipment are given in Table 1.29.

TABLE 1.29

Selection of detergents and sanitizers

Material	Cleaning	Sanitization
Stainless steel	All alkalis may be used. Care should be taken with acids.	All sanitizers may be used.
Mild steel	All alkalis may be used. Acids should be used together with inhibitors.	–do–

Material	Cleaning	Sanitization
Tinned steel/ copper	Weak alkalis, together with sodium sulphite as inhibitor, should be used.	All sanitizers may be used.
Bronze	-do-	-do-
Galvanized	-do-	-do-
Aluminium alloy	Weak alkalis, together with sodium silicate as inhibitor, should be used.	-do- -do-
Glass	All alkalis and acids may be used.	-do-
Vitreous enamel	Weak alkalis, together with sodium silicate as inhibitor, should be used.	-do-
Plastics	Cleaning temperatures should not be above the softening point of plastic.	Only chemical sanitizers should be used.
Rubber	Strong alkalis should be used to remove any fatty material stuck to the surface.	-do-

Note. (i) Chlorine sanitizers, if left in contact with metal surfaces, cause corrosion. Hence they should preferably be used just before processing.

(ii) Inhibitors are substances which minimize the corrosive action of acids or alkalis on metal surfaces. *Examples*: Sodium sulphite for a tinned surface and sodium silicate for an aluminium/aluminium-alloy surface.

The choice of general purpose detergents in organized dairies is given in Table 1.30.

TABLE 1.30

Choice of detergents in organized dairies

S. No.	Ingredients	Quantity	Remarks
1.	Tri-sodium phosphate	850 g.	For general use
	Wetting agent	150 g.	
2.	Tri-sodium phosphate	650 g.	For aluminium utensils
	Sodium meta-silicate	200 g.	
	Wetting agent	150 g.	
3.	Tri-sodium phosphate	750 g.	For tinned utensils
	Sodium sulphite	100 g.	
	Wetting agent	150 g.	

Note. (i) Under Indian conditions, tri-sodium silicate is usually replaced by sodium carbonate, mainly due to the lower cost and easy availability of the latter. However, sodium carbonate has a lower cleaning efficiency than tri-sodium silicate.

(ii) In organized dairies, the sanitizers chosen may be steam, scalding water (90 to 95°C) or chlorine solution (150 to 200 ppm. available chlorine).

II. *Methods.* These include hand washing, mechanical washing and cleaning-in-place (or in-place-cleaning).

(aa) *Hand washing.* (a) The normal cleaning and sanitization of hand-washed dairy equipment in organized dairies should be done as follows:

(i) Prepare 0.8 to 1.0 per cent of the detergent mixture (any set in Table 1.29) in tap water, so as to give a minimum alkalinity of 0.5 per cent (pH over 11.0) in a wash-up tank and maintain the temperature at about 50°C.

(ii) Thoroughly rinse the utensils with clean cold water (or tepid water in winter).

(iii) Introduce the detergent solution into the equipment (quantity of solution to be determined by requirement and experience). Thoroughly brush the equipment surface, inside and outside, with a clean can-brush.

(iv) Wash the utensil with enough fresh cold water (tepid water in winter), using a clean brush again if needed, to remove all traces of detergent.

(v) Allow the equipment to drain thoroughly and let it dry (for at least one to two hours).

(vi) Sanitize the equipment surface by steam or hot water after cleaning, and/or by rinsing with chlorine solution (200 ppm. available chlorine) just before using.

Note. (i) Use rubber gloves to avoid skin injury from detergent action.

(ii) Two compartment wash-up tank, one for warm detergent solution and the other for hot water (with a drain outlet in each tank) together with a steam jet/chest is helpful.

(iii) Use fresh detergent and sanitizing solutions.

(b) Bottles may be hand-washed as follows: The operator uses either a hand-brush or a motor-driven brush, and a mild alkaline solution which will not be injurious to the hand. A three-compartment tank (with a drainage outlet for each) is helpful; table space at both ends should also be provided. Two-thirds of the first compartment is filled with water at 50–55°C containing alkali detergent (any set in Table 1.29). The second compartment is filled similarly with water only at 50-55°C. The third compartment contains enough clean cold water, with 150 to 200 ppm. available chlorine. The (drained) bottles are put into the first compartment, and allowed to soak there for a few minutes, then brushed with a clean bottle-brush both inside and outside. After brushing, the bottles are placed in the second compartment where they remain until all bottles in the batch are washed. Then a new batch of bottles is placed in the first compartment to be soaked; and the bottles in the second compartment, after careful emptying, are placed in the third compartment; the bottles remain here while the second batch of bottles is brushed and transferred from the first to the second compartment. The crates are also carefully cleaned, inside and outside, and the bottles from the third compartment left upside down to be drained and dried. (As before, use rubber gloves to avoid skin injury from detergent action and as a protection against broken bottles, and use fresh detergent and sanitizing solutions when needed.)

(bb) *Mechanical washing.* This consists mainly of can- and bottle-washing:

(a) *Can-washing.* Cans may be cleaned and sanitized either manually or mechanically. The mechanical can-washer may be of either the Rotary or Straight-through/Tunnel type. The rotary can-washer is used in small plants; in this loading and unloading are done at the same point, and the cans move in a circle. The capacity usually ranges from 2 to 6 cans and lids per minute. *Advantages*: (i) occupies little space; (ii) machine can be operated by a single worker. The straight-through type is used in bigger plants; in this loading is done at one end and unloading at the other, and the cans move in a straight line. The capacity usually ranges from 4 to 12 cans and lids per minute. *Advantage*: (i) Greater capacity.

The cleaning and sanitization procedure for mechanical can-washing (can and lid) consists of the following stages:

(i) drainage stage for liquid milk residues;

(ii) pump-fed pre-rinsing with cold or luke-warm water;

(iii) drainage stage;

(iv) pump-fed jetting with detergent at not less than 70°C;

(v) drainage stage;

(vi) rinsing stage, pump-fed or by steam and water ejector at not less than 88°C;

(vii) final fresh water rinsing with steam and water ejector at 88 to 93°C;

(viii) live-steam injection;

(ix) hot-air drying at 95 to 115°C.

Note. (i) Detergent mixture used should be suitable for the can metal; not more than 0.5 per cent alkalinity is desirable.

(ii) Sanitization with chlorine is not recommended for tinned milk cans since it attacks tin-surfaces, especially if left in contact with the tin for any length of time.

(b) *Bottle-washing.* The mechanical bottle-washer may either be a Soaker (soaking), or Hydro (jetting) or Soaker-Hydro (part soaking and part jetting). Further, it may be of the Come-back or Straight-through type; in the former, loading and unloading take place at the same end, while in the latter they are done at opposite ends. Generally, soaker-hydro-come-back types are popular for small capacities, and straight-through-hydro types are used for larger capacities. In all machines, bottles are loaded manually or semi-automatically with manual assistance, and are discharged automatically onto one or more conveyors.

The stages of treatment in a mechanical bottle-washer are given below:

(i) *Pre-rinse*, using water at 32 to 38°C.

(ii) *Detergent wash*, usually 1–3 per cent caustic soda, together with chelating and wetting agents, given preferably in two stages at different temperatures within 60 to 75°C. *Sanitizes the bottles as well.*

(iii) *Warm water rinse*, to remove all traces of detergent. Reduces bottle temperature for next stage. Water temperature varies from 25 to 45°C and is usually re-circulated.

(iv) *Cold water rinse*, normally re-circulated chlorinated water (containing 35 to 50 ppm. available chlorine) is used to prevent re-contamination of bottles.

(v) *Draining*, after the bottles come out of the machine.

Note. Visual inspection of washed bottles is important. Under Indian conditions, this is done by workers examining each bottle through a large magnification lens. In developed dairying countries, an electronic device (Rototector) is used for detection of foreign matter in glass bottles, although it is not entirely satisfactory.

(cc) *Cleaning-in-place* (CIP)

(a) *Definition.* Also called In-place-cleaning (IPC). This refers to that system of cleaning and sanitization which does not require the daily dismantling of dairy equipment.

(b) *Merits.* The merits of the CIP system are:

(i) Ensures that all equipment receives uniform treatment day after day, by eliminating the human factor;

(ii) less damage to equipment (due to daily dismantling and assembling);

(iii) saving of (25 per cent or more) total clean-up costs and in man-hours;

(iv) reduces possibility of contamination through human error;

(v) improved plant utilization and appearance.

(c) *Success factors.* The success of the CIP system depends upon:

(i) Proper selection of pipes and fittings, installation and development of circuits;

(ii) proper temperature of cleaning solution;

(iii) adequate velocity of cleaning solution;

(iv) use of detergents designed specifically for re-circulation cleaning;

(v) proper concentration of detergent solution;

(vi) sufficient cleaning time.

(d) *Types.* The types of CIP systems are:

1. *Manual control.* In this case, the completion and setting up of the product and CIP-circuits is done manually, the valves are hand-operated and the entire process is controlled by the operator. (The use of key-pieces is recommended for safety.)

2. *Automation.* Broadly speaking, the levels may be:

(i) *Low level.* Setting up of CIP and product-circuits is done automatically.

(ii) *Medium level.* Setting-up of CIP and product-circuits as well as the different types of treatment are all controlled automatically.

(iii) *High level.* Use of computer for complete control of the entire product manufacture and CIP system in large plants.

(e) *Procedure.*

1. *HTST Pasteurizer.* The CIP method of cleaning and sanitization of the HTST pasteurizer is as follows:

(i) Pre-rinse, with cold or tepid water till discharge water runs clear.

(ii) Acid-rinse, with acid (phosphoric) solution of 0.15 to 0.60 per cent acidity, re-circulated at 65 to 71°C for 20 to 30 minutes. (Wetting agent may be added to increase cleaning ability.)

(iii) Drain out acid solution.

(iv) Hot water rinse, with water at 65 to 71°C for 5 to 7 minutes. Rinse water drained out.

(v) Alkali rinse, with alkali detergent solution of 0.15 to 0.60 per cent alkalinity, re-circulated at 65 to 71°C for 20 to 30 minutes. (Wetting agent may be added to increase cleaning ability.)

(vi) Drain out alkali solution.

(vii) Final hot water rinse, with water at 71 to 82°C, till the whole system has been heated. Rinse water drained out. Then slightly loosen plates for drainage and drying.

Note. (i) Nitric acid may be used with stainless steel plates.
(ii) At regular intervals, the equipment may be dismantled for thorough cleaning and inspection of all milk contact surfaces.

2. *Milk Storage Tank/Milk Tankers.* The programme of cleaning and sanitization of milk storage tanks or milk tankers by the CIP method is given below. Especially designed spray arms and nozzles (turbine or ball spray) are normally used to ensure uniform spraying of detergent and sanitizing solutions over the surface:

(i) Pre-rinse with tap water;

(ii) drain for 3 to 5 minutes;

(iii) hot detergent wash with sodium hydroxide solution (sodium hydroxide 90 parts, sodium thiosulfate 9 parts and wetting agent 1 part) of 0.35 to 0.50 per cent strength at 71°C for 15 to 20 minutes. Once or twice a week, an acid-alkali programme may be used. The acid may be phosphoric or nitric; this should be followed by alkali as above.

(iv) Drain for 3 to 5 minutes.

(v) Post-rinse with hot water at 65 to 70°C.

(vi) Drain for 3 to 5 minutes.

(vii) Sanitize, usually with hot water at 90°C for 2 to 3 minutes, otherwise with chlorine solution at 15 to 20°C containing 150 to 200 ppm available chlorine for a contact time of 1 to 2 minutes.

(viii) Drain for 3 to 5 minutes.

(ix) Hot air blow for 1 to 2 minutes.

(f) *Systems.* These are:

(i) *Total loss system.* In this, the detergent solutions are drained out after use. *Advantages*: (i) less steam required for heating water; (ii) compact CIP unit; and (iii) fewer pipelines.

(ii) *Saving solutions system.* The detergent solutions are returned to their respective tanks. The strength of the solutions, however, is maintained automatically. *Advantage*: (i) Saving in detergent solutions.

Note. The system to be used will depend largely on the hardness of water and the type of soil.

1.20 Judging and Grading of Milk

A. *Introduction.* Judging of milk refers to the act of evaluating its 'Eating Quality' on the basis of various attributes. Grading refers to its classification into different grades. The 'Eating Quality' of a dairy product is determined by organoleptic/sensory tests, which include all the five senses of sight, smell, taste, touch and sound. Of these, taste and smell are the most important in judging and grading.

B. *Importance.* The consumer acceptability of a dairy product is determined primarily by its eating quality, i.e. by the sensations of smell, taste, feel, etc., which the consumer experiences when the product is tasted or consumed. It is well known that dairy products cannot be of a higher quality than the raw material from which they are made. Hence, milk producers should have definite knowledge as to what constitutes desirable and undesirable flavours in milk, as well as the factors causing them; only then will they be in a position to produce milk that would make high-scoring finished products. A processor of milk (and manufacturer of dairy products) should have the ability to discriminate against certain objectionable flavours and manufacturing defects; and to recognize desirable flavours and make-up characteristics, since these will enable him to make a product of good consumer acceptability. The consumer should have adequate knowledge of desirable and undesirable flavours in milk and milk products, as these will enable him to purchase the same wisely and get his money's worth.

C. *Score Card.* This is given in Table 1.31.

TABLE 1.31

Score card for milk and cream (ADSA)

Items	Perfect score
Flavour (smell and taste)	45
Bacteria	35
Sediment	10
Temperature	5
Container and closure	5
Total	100

D. *Procedure for Examination (and scoring)*

(a) *Sampling.* Secure a representative sample aseptically by the standard procedure for bacterial count determination.

(b) *Sequence of observations.*

(i) *Sediment.* The sediment discs should be compared with standard charts for scoring. (However, sediment scoring of packaged milk is no longer done in standard contests.)

(ii) *Closure (cap).* After having scored for sediment, the closure should be carefully observed and scored.

(iii) *Container.* The glass container is examined next for fullness, cleanliness and freedom from cracks and chips, particularly about the pouring lip. The paper container is examined for cleanliness, freedom from leakage, smoothness and the adherence of a coating to its surface. Correct fillage can be determined only by actual measurement of the volume of milk in a graduated cylinder.

(iv) *Flavour* (smell and taste). This is scored only after the above items have been considered. The temperature of the milk should be around 16–21°C (60–70°F). The milk should be well-mixed before it is sampled in a small clean drinking-glass/beaker/paper-cup. As soon as the milk sample has been taken, sip (but do not swallow) a sufficient amount of it (5 to 10 ml.) to yield a normal taste reaction and yet one sufficiently small to permit its easy manipulation in the mouth. Roll it about the mouth, note the flavour and sensation, and then expectorate it. Note the after-taste as well. By placing the nose directly over the milk when it has been shaken, any off-smell may be detected.

E. *Requirements of High-Grade Market Milk*

(i) The container should be neat and clean and contain the full volume of milk represented. The milk in the bottle should be protected from contamination by a well-made, well-seated, waterproof cap, which protects the pouring lip fully. The bottle itself should be bright, shining, free from dirt, dust, etc.; it should not be cracked or chipped, particularly on the pouring lip. Paper/plastic containers should be clean and fresh with no leakage, pronounced bulging, etc.

(ii) The milk should be delivered at 10°C or below.

(iii) It should have the least amount of sediment.

(iv) It should have a low bacterial count. (High quality milk is low in bacteria, but low-bacteria milk may not always have the best flavour.)

(v) The flavour of the milk should be pleasantly sweet, and should have neither a foretaste nor an aftertaste, other than what is imparted by its natural richness.

F. *Grades of manufacturing milk*. Although there should be a single minimum standard of quality for all milk, whether it is to be used directly as fluid milk or for the manufacture of various products, this is not so in practice. The following classification may be used:

(a) *Grade I.* Milk with a clear pleasant flavour, MBR time over $5\frac{1}{2}$ hours and practically no sediment on sediment disc. (Tolerance for: slightly feed, flat or salty off-flavours.)

(b) *Grade II.* Milk having off-flavours such as: definitely feed, flat or salty; slightly barny, bitter, foreign, malty, metallic, musty, oxidized or rancid; or very slightly weedy; MBR time between $2\frac{1}{2}$ and $5\frac{1}{2}$ hours; or milk which shows a medium amount of sediment.

(c) *Grade III.* Milk having off-flavours such as: definitely barny, bitter, foreign, malty, metallic, musty, oxidized or rancid; or slightly high-acid; MBR time between 20 minutes and 2½ hours; or definitely high in sediment.

(d) *Reject or no grade.* Milk with markedly high-acid, rancid, weedy, or foreign flavours; MBR time of less than 20 minutes and containing an extremely high amount of sediment or any noxious foreign matter.

Note. The use to which each grade of milk is put will depend upon public health regulations concerning conditions of production and upon the specific character of the product. In general, the following categorization may be made:

Grade I = Market milk, Sterilized milk, Evaporated milk, Sweetened condensed milk, Milk powder (whole or skim); Infant food, Cheese, etc.

Grade II = Butter, Ice cream, Flavoured milks, Fermented milks, Khoa, Chhana/Paneer, Butteroil, Ghee, etc.

Grade III = Ghee, Casein, etc.

1.21 Flavour Defects in Milk, their Causes and Prevention

Milk has a flavour defect (i.e. off-flavour) if it has an undesirable smell, foretaste or aftertaste, and if the mouth does not feel clean and pleasant after it has been tasted. These flavour defects may arise due to faulty methods of production, processing and storage. The common flavour defects in milk, their causes and prevention are given in Table 1.32.

TABLE 1.32

Flavour defects in milk, their causes and prevention

Flavour defects	Causes	Prevention
Barny	(i) Improper ventilation of milking byre/barn; (ii) Milk not properly covered during production.	(i) Proper ventilation of milking byre/barn; (ii) Keep milk properly covered during production.
Bitter	(i) Intake of bitter weeds by milch animals; (ii) Using late lactation milk.	(i) Eradicate offending weeds; (ii) Use normal lactation milk.

Flavour defects	Causes	Prevention
Cooked	Overheating of milk.	Avoid overheating of milk.
Feed	Feeding of milk-tainting feeds (such as silage) within 3 hours before milking.	Feed milk-tainting feeds (such as silage) soon after milking.
Foreign	Addition or absorption of foreign smelling substances in milk.	Avoid contact of milk with foreign smelling substances.
High-acid/Sour	Excessive lactic acid development (due to considerable growth of lactic acid producing micro-organisms).	Store milk at 5°C (40°F) or below (to check bacterial growth and acid development).
Malty	Growth of *Str. lactis* var. *maltigenes* micro-organisms in milk.	Store milk at 5°C (40°F) or below to check bacterial growth.
Rancid	Fat hydrolysis due to lipase action.	Inactivate lipase by proper pasteurization of milk.
Oxidized, Oily, Metallic, Tallowy	Fat oxidation due to: direct contact of milk with copper or iron, exposure of milk to light, etc.	(i) Tin milk - holding vessels properly; or use aluminium alloy/stainless steel as milk-contact surfaces; (ii) De-aerate/vacuumize pasteurized milk.
Salty	Milk of animals suffering from mastitis, or far advanced in lactation.	Avoid mastitis or late lactation milk.
Weedy	Intake of milk-tainting weeds (within 3 hours of milking).	(i) Eradicate milk-tainting weeds; (ii) Vacuum pasteurization of milk.

Note. In the souring of milk, lactic acid is the main fermentation product, but the sour smell is not caused by lactic acid (which is non-volatile). Volatile substances, such as acetic acid, formic acid, propionic acid, acetaldehyde, acetone, diacetyl and methyl-acetyl carbinol, are responsible for the characteristic smell of sour milk.

1.22 Uses of Milk

(i) In the daily diet, as a nutritive food for pregnant mothers, growing children, adolescents, adults, the aged, invalids, convalescents and patients alike;

(ii) as raw material for the production of various processed milks and manufactured products;

(iii) in bakeries and confectionaries;

(iv) as an additive to improve the quality of various recipes.