Lecture Compendium

SENSORY EVALUATION AND RHEOLOGY OF MILK AND MILK PRODUCTS

The Second Short Course

Organised under the aegis of Centre of Advanced Studies in Dairy Technology

August 22 - September 13, 1996

Dairy Technology Division
National Dairy Research Institute (ICAR)
Karnal - 132 001
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Mr. Alok Jha
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Dr. V. K. Gupta

Cover Design
Dr. B. N. Mathur
FOREWORD

Ever since the dawn of civilisation the food that man eats has always been 'judged' or tasted beforehand, but with the advent of the processing industry, the concept of sensory evaluation has been revolutionised. The evolution of human senses seems to have progressed hand-in-hand with the practice of sensory evaluation. I would even say that it has evolved into a branch of biotechnology. Here it would be worthwhile to make a reference to a recent development in the Netherlands where the Unilever Research Laboratory has evolved antibodies against odour molecules, which function the same way as the olfactory receptors in the nasal cavity by binding to the molecules. These antibodies can serve as a model to study the interactions between say, modified odour molecules and the receptors.

Interestingly, among various food products, dairy products besides tea are the ones that have not only been identified with sensory evaluation but have led the sector 'from the front'. It is also known that in countries like USA judging is an integral part of the quality assurance programmes of most dairy plants. In attempts to provide a similar support to the dairy food processing industry in this country the Bureau of Indian Standards has, with inputs from this Institute, CFTRI and the industry, made notable contributions by formulating guidelines and evaluation procedures for several dairy products. Further, with the rapidly growing competition in the post-GATT era, sensory evaluation will certainly have a key role to play in the Indian dairy industry.

Instrumental evaluation of texture well as flavour and colour is very valuable in complementing the sensory judgement. Texture measurement in terms of basic rheological parameters can not only have far-reaching implications in product quality evaluation, but would play an important role in product and process development as well as in process control. Obviously, indigenous milk products stand to gain a great deal in this regard. Today several highly versatile microprocessor-controlled rheological instruments have taken the place of old, empirical methods. A particularly noteworthy engineering contribution in this area is the development of novel in-line viscometers such as those based on the principles of nuclear magnetic resonance (NMR), or on that of dynamic measurements.

It is heartening to note that the Division of Dairy Technology has kept up the pace of activities under the banner of "Centre of Advanced Studies" by organising the second short course on the heels of the highly successful one on Membrane Technology earlier this year. Needless to say, the subject of this course is greatly relevant to the needs of the present-day dairy industry. It is my sincere belief that the participants will have a lot to learn from the highly qualified and trained faculty of the Division. It is hoped that the compendium so ably brought out by the course organisers will serve as a reference work of immense importance to the participants of the course in their research and teaching endeavours. It will also prove an important source of information on the topic for various SAU libraries.

August 17, 1996

(O. S. Tomer)
DIRECTOR
Establishment of the Centre of Advanced Studies in Dairy Technology at the National Dairy Research Institute, Karnal has been recognition of the pioneering role this Department has played in the development of the human resource for middle and top level management as well as R&D support for the Dairy Industry in India. For further pursuit of the Council's policy to establish working linkages between the State Agricultural Universities, Deemed Universities of the ICAR and the leading R&D Institutions of the Country, we are pleased to have the opportunity to arrange this short course. In this regard, we place on record our gratitude to the Council, specially towards Dr. S. L. Mehta, who has taken a keen interest in implementing the CAS scheme at NDRI. Organisation of this short course would not have been possible without the wholehearted support of Dr. O. S. Tomer, Director, NDRI, who placed all the support systems at our disposal for managing various activities concerning this important event. We acknowledge gracious support from him for managing activities of the CAS and this short course in particular.

The credit for establishing the basic infrastructure concerning the discipline of Sensory Evaluation and Rheology goes to Dr. S. K. Gupta, Principal Scientist. During his formative years during 1970s, he took very keen interest in establishing the SE Laboratory and later played key role in inviting Consultants from USA under the UNDP programme for further strengthening this field of study in the Department. As the Co-ordinator of the short course, Dr. Dharam Pal has worked with diligence to provide the scientific support and carried out liaison with various support systems in the Institute. The prominent role played by both of them in organising this workshop is gratefully acknowledged.

Compilation of various lectures into a compendium was indeed an awesome task that required skilful editing of the text, co-ordinating word-processing, and voluminous photocopying. For all this excellent work, we are grateful to Dr. A. A. Patel and his very able team consisting of Drs. K. V. S. S. Rao, Sudhir Singh, V.K. Gupta, R. R. B. Singh and Mr. Alok Jha. Technical support in designing and printing of the cover pages from Mr. D. K. Gosain and the NDRI Press for binding in this publication in aesthetically appealing form deserves a special mention. Help received from Dr. G. S. Rajorhia, In-charge, Library Services in photocopying was very timely and useful in following the time schedule of this publication.

We are specially thankful to the Guest Lecturers, Dr. (Ms) Rashmi Mathur, Assoc. Prof. (Physiology), AIIMS, New Delhi and Dr. G. R. Patil, Professor, MAU, Parbhani as well as all participating Faculty of the Institute who have contributed to the short course content and have enriched the subject matter content with their expertise.

We place on record help received from various quarters, which may be all too many to be mentioned individually, but without their support this publication would not have been possible.

(B. N. Mathur)
Director, CAS/DT
COMMITTEES FOR COURSE ORGANISATION

ORGANISING COMMITTEE

Dr. B.N. Mathur, Course Director
Dr. S.K. Gupta
Dr. G.S. Rajorhia
Dr. B.D. Tiwari
Dr. A.A. Patel
Dr. R.S. Mann
Dr. R.S. Patel
Dr. Dharam Pal, Course Coordinator

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Dr. C.N. Pagote

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Dr. Dharam Pal
Dr. D.K. Thompkinson
Mr. F.C. Garg
COURSE PROGRAMME

August 22, 1996
9.30 AM - 10.00 AM  Registration
10.00 AM - 11.30 AM  Inaugural function
11.30 AM - 12.00 Noon  Tea
12.00 Noon - 1.00 PM  Orientation and visit to the Institute  Sh. D.K. Sharma
1.00 PM - 2.30 PM  Lunch break
2.30 PM - 3.30 PM  Introduction to sensory evaluation and rheological measurements of milk & milk products  Dr. B.N. Mathur
3.30 PM - 3.45 PM  Discussion
3.45 PM - 4.45 PM  Visit to Computer Centre  Dr. D.K. Jain

August 23, 1996
10.00 AM - 11.00 AM  L  Role of primary senses in sensory evaluation  Dr. S.K. Gupta
11.00 AM - 11.15 AM  Discussion
11.15 AM - 12.15 PM  L  Requirements for sensory evaluation  Dr. Dharam Pal
12.15 PM - 12.30 PM  Discussion
1.00 PM - 2.30 PM  Lunch break
2.30 PM - 4.00 PM  L-P  Threshold value and its determination  Dr. Dharam Pal

August 24, 1996
10.00 AM - 11.00 AM  L  Rheological classification of foods  Dr. A.A. Patel
11.00 AM - 11.15 AM  Discussion
11.15 AM - 12.15 PM  L  Selection and training of sensory test panel  Dr. S.K. Gupta
12.15 PM - 12.30 PM  Discussion
1.00 PM - 2.30 PM  Lunch break
2.30 PM - 4.45 PM  P  Odour and texture identification  Dr. Dharam Pal & Mr. F.C. Garg

August 25, 1996
August 26, 1996
10.00 AM - 11.00 AM  L  Sensory tests - I  Dr. Dharam Pal
## Programme

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<th>Speaker(s)</th>
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<tr>
<td>11.00AM</td>
<td>Discussion</td>
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<tr>
<td>11.15AM</td>
<td>Rheology and food dispersions</td>
<td>Dr. A.A. Patel</td>
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<tr>
<td>12.15PM</td>
<td>Discussion</td>
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<tr>
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<td>Dr. Dharam Pal &amp; Mr. D.K. Sharma</td>
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<td>Dr. Dharam Pal</td>
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<td>11.15AM</td>
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<tr>
<td>2.30PM</td>
<td>Stress-shear rate relationship in liquid dairy products</td>
<td>Dr. R.R.B. Singh &amp; Mr. Anrudh Kumar</td>
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**August 28, 1996**

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<td>Prof. V.P. Aneja</td>
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<tr>
<td>2.30PM</td>
<td>Judging of milk</td>
<td>Dr. Dharam Pal &amp; Mr. F.C. Garg</td>
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**August 29, 1996**

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<td>10.00AM</td>
<td>Role of food flow properties in process equipment design</td>
<td>Dr. H. Abichandani</td>
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<td>Discussion</td>
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<tr>
<td>11.15AM</td>
<td>Viscoclasticity of foods and rheological models</td>
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<td>12.15PM</td>
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<tr>
<td>2.30PM</td>
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<td>Dr. G.R. Patil &amp; Dr. A.A. Patel</td>
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<td>10.00AM</td>
<td>Physiology of taste and odour</td>
<td>Dr. (Ms) Mathur (Guest Speaker)</td>
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<td>11.00AM</td>
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<tr>
<td>11.15AM</td>
<td>Psychorheology of foods</td>
<td>Dr. G.R. Patil</td>
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<td>12.15PM</td>
<td>Discussion</td>
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## Programme

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<td>2.30 PM - 4.45 PM</td>
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<td>Judging sensory attributes of table butter</td>
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<td>10.00 AM - 11.00 AM</td>
<td>L</td>
<td>Sensory attributes of fresh cheese</td>
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<td>11.00 AM - 11.15 AM</td>
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<td>11.15 AM - 12.15 PM</td>
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<td>Sensory attributes of milk protein products</td>
<td>Dr. V.K. Gupta</td>
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<td>12.15 PM - 12.30 PM</td>
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<td>Discussion</td>
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<td>1.00 PM - 2.30 PM</td>
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<td>Lunch Break</td>
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<tr>
<td>2.30 PM - 4.45 PM</td>
<td>L-P</td>
<td>Tristimulus colour measurement in foods</td>
<td>Dr. V.K. Gupta</td>
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<td>Sept. 1, 1996</td>
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<td>10.00 AM - 11.00 AM</td>
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<td>Chemistry of ghee flavour and related aspects</td>
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<td>11.00 AM - 11.15 AM</td>
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<td>Discussion</td>
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<td>11.15 AM - 12.15 PM</td>
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<td>12.15 PM - 12.30 PM</td>
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<td>Discussion</td>
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<td>1.00 PM - 2.30 PM</td>
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<td>Lunch Break</td>
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<tr>
<td>2.30 PM - 4.45 PM</td>
<td>P</td>
<td>a) Judging and texture profile analysis of cheese</td>
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<td>10.00 AM - 11.00 AM</td>
<td>L</td>
<td>Rheological properties of solid milk products</td>
<td>Dr. A.A. Patel</td>
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<td>11.00 AM - 11.15 AM</td>
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<td>Discussion</td>
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<tr>
<td>11.15 AM - 12.15 PM</td>
<td>L</td>
<td>Sensory attributes of concentrated milks and their evaluation</td>
<td>Mr. D.K. Sharma* &amp; Mr. Alok Jha</td>
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<tr>
<td>12.15 PM - 12.30 PM</td>
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<td>1.00 PM - 2.30 PM</td>
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<tr>
<td>2.30 PM - 4.45 PM</td>
<td>L-P</td>
<td>Sensory attributes of dried milks and their evaluation</td>
<td>Mr. Alok Jha* &amp; Dr. R. S. Mann</td>
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<td>Sept. 4, 1996</td>
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<td>10.00 AM - 11.00 AM</td>
<td>L</td>
<td>Sensory attributes of ghee</td>
<td>Dr. G.S. Rajorhia</td>
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<td>11.00 AM - 11.15 AM</td>
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<td>Discussion</td>
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<td>Time</td>
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<td>11.15 AM - 12.15 PM</td>
<td>SEM technique for the study of Microstructure of dairy products</td>
<td>Dr. D.N. Prasad</td>
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<td>12.15 PM - 12.30 PM</td>
<td>Discussion</td>
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<td>2.30 PM - 3.30 PM</td>
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<td>Dr. M.P. Bindal Mr. K. L. Arora &amp; Dr. Dharam Pal</td>
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<tr>
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<td>P Judging of ghee</td>
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<td>10.00 AM - 11.10 AM</td>
<td>L Sensory attributes of traditional milk products</td>
<td>Dr. G.S. Rajorhita</td>
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<td>11.00 AM - 11.15 AM</td>
<td>Discussion</td>
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<td>Lunch Break</td>
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<td>2.30 PM - 4.45 PM</td>
<td>P Demonstration of electron microscopy techniques</td>
<td>Dr. D.N. Prasad</td>
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<td>Visit to a Dairy Plant</td>
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<td>10.00 AM - 11.00 AM</td>
<td>L Sensory evaluation in product development</td>
<td>Dr. K. V. S. S. Rao</td>
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<td>11.00 AM - 11.15 AM</td>
<td>Discussion</td>
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<td>11.15 AM - 12.15 PM</td>
<td>L Sensory attributes of ice-cream</td>
<td>Dr. Abhay Kumar</td>
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<td>12.15 PM - 12.30 PM</td>
<td>Discussion</td>
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<td>1.00 PM - 2.30 PM</td>
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<td>2.30 PM - 4.45 PM</td>
<td>P a) Judging of traditional dairy products other than ghee. b) Judging of whey-based soups</td>
<td>Dr. Dharam Pal &amp; Mr. F. C. Garg Dr. Sudhir Singh</td>
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<td>10.00 AM - 11.00 AM</td>
<td>L Sensory attributes of selected fermented milk products</td>
<td>Dr. R. S. Patel</td>
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<td>11.15 AM - 12.15 PM</td>
<td>L Texture and structure of heat-and-acid-coagulated indigenous milk products</td>
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<td>Discussion</td>
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<td><em>Lunch Break</em></td>
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| 2.30 PM - 4.45 PM P | a) Use of Carri-Med Rheometer for fluid dairy products rheology *Dr.A.A.Patel*  
|              | b) Judging of ice-cream *Mr.F.C.Gorg*

**Sept. 11, 1996**

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| 10.00 AM - 11.00 AM L | Packaging for better preservation of the sensory quality processed foods *Dr.G.K.Goyal*
| 11.00 AM - 11.15 AM | Discussion                                 |
| 11.15 AM - 12.15 PM L | Statistical methods in sensory evaluation *Dr.D.K.Jain*
| 12.15 PM - 12.30 PM | Discussion                                 |
| 1.00 PM - 2.30 PM | *Lunch Break*                              |
| 2.30 PM - 3.30 PM P | Use of computer in analysis of sensory data *Dr.D.K.Jain*
| 3.30 PM - 4.45 PM P | Judging of fermented milks *Dr. R. S. Patel & Dr.C.N. Pagote*

**Sept. 12, 1996**

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| 10.00 AM - 11.00 AM L | Sensory properties of vegetable protein products as ingredients for dairy analogs *Dr.R.B.Rajor*
| 11.00 AM - 11.15 AM | Discussion                                 |
| 11.15 AM - 12.15 PM L | Consumer acceptance studies *Mr.D.K.Sharma*
| 12.15 PM - 12.30 PM | Discussion                                 |
| 1.00 PM - 2.30 PM | *Lunch Break*                              |
| 2.30 PM - 4.45 PM L | Interactions with the faculty              |

**Sept. 13, 1996**

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<tr>
<td>10.00 AM - 11.00 AM</td>
<td>Valedictory function</td>
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Foreword

Dr. O.S. Tomer

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Acknowledgements

Dr. B.N. Mathur

Committees for course organisation

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Course programme

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**I. INTRODUCTION**

1 Introduction to sensory evaluation and rheological measurements of milk and milk products

Dr. B.N. Mathur

1

**II. SOME BASIC ASPECTS OF SENSORY EVALUATION OF FOOD**

2 Role of primary senses in sensory evaluation

Dr. S.K. Gupta

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3 Requirements for sensory evaluation

Dr. Dharam Pal

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4 Threshold value and its determination

Dr. Dharam Pal

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I. INTRODUCTION
INTRODUCTION TO SENSORY EVALUATION 
AND RHEOLOGICAL MEASUREMENTS OF 
MILK & MILK PRODUCTS

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1. INTRODUCTION

Sensory Evaluation (SE) as a scientific discipline represents a very unique technique that harnesses human behavioural instincts of perception, learning, cognition, psychophysics and psychometrics for the evaluation of quality of foods. Techniques of SE and rheological measurements have played key role in building up modern food processing industry based on the development of a wide range processed food products, quality assurance systems and promotion of international trade. In contrast to the instrumental methods (e.g., spectrophotometry, GLC, HPLC, etc.) that permit measurement of one parameter at a time, SE technique permits integrated measurement of the food quality as a whole. Rheological methods are intended to measure one or more well defined physical properties and to relate these to textural characteristics of the food. The complex and variable structure of foods and wide spectrum of textural behaviour which they exhibit give rise to difficulties in applying such fundamental methods. By comparing panellists' evaluation of the sensory properties with instrumental measurements performed under conditions closely simulating those to which the foods are subjected during panellists' evaluations, a deeper understanding has been achieved of the mechanics of SE. Thus, SE and rheological measurements for evaluation of quality of milk and milk products are subjects of continuing research.

2. CHRONOLOGICAL PERSPECTIVE

During the history of human civilisation, senses of tastes and smell must have influenced present day food habits and taboos of various ethnic groups. Exact sensory analysis of food is of relatively recent origin, when in about 1940 Scandinavian countries developed the concept of 'triangle test'. By 1950s, systematic studies had led to the standardisation of techniques of sensory analysis and were in vogue in the European food industry. At the same time, independent and analogous studies were being carried out in the USA and Japan. During the last two decades, sensory analysis has developed into a science. A number of countries (in particular, Deutsches Institut fuer Nahrung) as well as international organisations (ISO) have developed definitions and standardised sensory testing methods. In the modern context, the sensory analyst can be compared to an instrument. Such an analyst measures sensory quality of a food product by using a well-defined quality scale.

3. SENSORY RECEPTORS

The sensory receptors are the detectors which inform us of physical and chemical changes in our environment. These specialised cells are usually sensitive to single stimulus, but under certain conditions may react with other stimuli. Various sense organs mediate a
spatial or chronological picture. The sense organs consist of sensory cells or group of cells which respond to the stimuli and transmit an impulse via the nervous system to the brain. Taste and smell constitute the special chemical senses of the human nervous system. In contradistinction to the chemical senses, the tactile sensations of touch, constitutes the somatic sense of the nervous mechanisms that collect sensory information from the body, such as the texture.

3.1 Sense of taste

Taste is mainly a function of the taste buds in mouth. In addition, the texture of food as detected by tactile senses of mouth, and presence of substances that stimulate pain endings, greatly condition the taste experience. The identities of specific chemicals that excite different taste receptors are still very incomplete. Even so, psychophysiological and neurophysiological studies have identified probable chemical perceivers as follows: sodium receptors (2), potassium receptors (2), chloride receptor (1), adenosine receptor (1), inosine receptor (1), sweet receptors (2), bitter receptors (2), glutamate receptor (1) and hydrogen ion receptor (1). For practical analysis of taste, however, these receptor capabilities have been grouped into four general categories called the primary sensation of taste. These are sour, salty, sweet and bitter. We know, of course that a person can perceive literally hundreds of different tastes. These are supposed to be combinations of the elementary sensations in the same manner as all colours that we can see are combinations of the three primary colours.

The intensity of sour taste is approximately proportional to the logarithm of hydrogen ion concentration. The salty taste is elicited by ionized salts, and the quality of salty taste varies from one salt to another. The cations of salts are mainly responsible, while anions contribute to a lesser extent. The sweet taste is caused by the presence of many classes of organic compounds, such as sugars, glycols, alcohols, aldehydes, ketones, amides, esters, amino acids, sulfonic acids, halogenated acids, as well as inorganic salts of lead and beryllium. It is specially interesting that very slight changes in the chemical structure such as addition of a simple radical, can often change the substance from sweet to bitter. The bitter taste sensation is caused by two particular classes of substances: long chain organic substances containing nitrogen and alkaloids (quinine, caffeine, strychnine and nicotine). Some substances that at first taste sweet have a bitter aftertaste, such as saccharin. The sensitivity for bitter taste is much higher, the threshold for quinine being 0.000008 M, compared to sour taste (0.0009 N for HCl), salty taste (0.01 M for NaCl) and sweet taste (0.01M for sucrose). It is nature's way of providing protection by distinguishing food, since most of the deadly toxins found in foods are alkaloids. Many people are taste blind for certain substances, specially for different types of thioarene compounds. Psychologists employ phenyl thiocarbamide to detect this disability for which approximately 15 - 30 % of all people exhibit taste blindness.

The taste buds are located on three different types of papillae of the tongue, being about 1/30 mm in diameter and about 1/15 mm in length. The taste bud is composed of about 40 modified epithelial cells, some of which are supporting cells (sustentacular cells) and others are taste cells. The outer tips of the taste cells are arranged around a minute taste pore. From the tip of each cell several microvilli protrude towards the cavity of mouth. These microvilli provide the receptor surface for taste. The membrane for the taste cell is negatively
charged on the inside. Application of the taste substances cause partial loss of the negative potential, causing cell to be depolarised. A strong immediate signal is transmitted by a taste nerve, and a weaker continuous response is transmitted as long as the taste bud is exposed to the taste stimulus. Subsequent to the transmission of taste signals into the central nervous system, taste reflexes are integrated in the brain stem directly into superior and inferior nuclei. Based on transmission of these impulses to the submandibular, sublingual, and parotid glands, excretion of saliva is controlled during ingestion of food.

3.2 Olfaction

The olfactory membrane lies in the superior part of each nostril. The receptor cells for the smell sensations are the olfactory cells, which are actually bipolar nerve cells deprived originally from the central nervous system itself. There are about 100 million of these cells in the olfactory epithelium interspersed among sustentacular cells. The mucosal end of the olfactory cell forms a knob from which 6 to 12 olfactory hairs, or cilia, 0.3 μm in diameter, and up to 200 μm in length project into the mucus that coats the inner surface of the nasal cavity. It is these cilia that react to the odours (chemical stimuli) and then stimulate the olfactory cells. The membranes of cilia contain a large number of proteins, which can bind a large number of odorant substances. It is presumed that this binding is necessary stimulus for exciting the olfactory cells. The binding of the odorant causes the protein to become an activated adenylate cyclase at its end that protrudes into the interior of the cell. The cyclase in turn catalyses formation of cAMP that causes transfer of charge to other cells. The membrane potential of unstimulated olfactory cells has been established at -55 mV. At this potential, most cells generate continuous action potentials at a rate varying from once every 20 seconds to two to three per second. Most olfactory receptors obey the principle of transduction similar to other sensory receptors.

Most physiologists are convinced that many smell sensations are subserved by a few rather discrete primary sensations, the same way that vision or taste are subserved by a few select sensations. These olfactory stimulants are characterised as follows: 1. camphoraceous; 2. musky; 3. floral; 4. peppermint; 5. ethereal; 6. pungent; and 7. putrid. However, it is unlikely that this list represents the true primary sensations of smell, even though it illustrates one of many attempts to illustrate them. Odour blindness is attributable to the lack of certain receptor protein in the olfactory cell, adding credence to the above postulation. In the food industry, significance of the odours has been appreciated strongly, because of the affective nature of smell as pleasant or unpleasant. Measurement of smell threshold represent several practical difficulties and methods are being constantly refined to eliminate interference causing factors.

3.3 Tactile Senses

The mechanoreceptive somatic senses, which include both tactile and position sensations are stimulated by mechanical displacement of some tissue of the body. The tactile senses mainly include touch, pressure, and vibrations. Mechanical stimulation of the skin results in tactile and kinaesthetic sensations. Pressure sensation generally results from the deformation of deeper tissues. There are at least six types of tactile detectors (viz., free nerve endings, Meissner's corpuscle, expanded tip tactile detectors, hair end organ, Ruffini's end organs, and pacinian corpuscles), which transmit sensations in peripheral nerve fibres that
eventually reach the central nervous system. Tactile receptors in the mouth are located on the tongue, gums, and hard and soft palate. Mastication (chewing) exerts considerable force, causing slight displacement of tooth in the socket. Chewing seems to afford its own pleasure, which happens rather compulsively.

4. SUBJECTIVE ANALYSIS OF FOOD TEXTURE

Mouthfeel of food ingested is described as the texture. It relates to density, viscosity, surface tension, and other physical properties of the food. Additionally, texture is referred to as finger feel (firmness, softness, or yield quality), and juiciness. Most researchers feel that sensory test is probably the only way to obtain meaningful information about texture.

In applying SE to describe the texture of milk and milk products, it is soon realised that a large number of terms are required to define the properties. If restricted to the foods that flow, for instance, terms such as viscosity, spreadability, creamy, gummy and slimy are employed. Pertinent studies have been carried out to evaluate the validity of consumer response studies, especially to know if these are instantly identified after a time gap. Attempts have also been made to correlate sensory methods with the instrumental methods of texture analysis, though with limited success.

5. OBJECTIVE STUDY OF FOOD TEXTURE

In its mechanical and geometrical qualities, texture is described in the primary parameters of hardness, cohesiveness, viscosity, elasticity and adhesiveness; and secondary parameters of brittleness, chewiness, and gumminess. Despite the significance and widespread use of rheological methods, difficulties still arise in defining rheology as applied to the quality of food.

Three broad categories of the texture measurement have been recognised: empirical, imitative and fundamental. Empirical methods usually involve measurement of the resistance to deformation offered by the sample. The properties measured are not well defined and the results cannot be expressed in fundamental terms. Such results are dependent on probe geometry, rate of deformation and sample size. This dependence is exemplified by results obtained using a simple cylindrical probe and a Kramer Shear Cell mounted on an Instron Universal Testing Machine. The need to calibrate empirical instrument is another limitation on their use.

Imitation methods attempt to simulate to some extent the action of the jaws and teeth when masticating food in the mouth. The General Foods Texturometer is a well known instrument in vogue in the food research. The instrument mechanisms is essentially based on a high initial stress. This being the main feature, clear evidence is not yet available to suggest that the results so obtained are in any way superior to those of other empirical instruments.

Fundamental methods are directed to measure one or more well defined physical properties of the food sample and relate these to the texture profile. Some kinaesthetic properties of foods can be determined objectively by instruments which measure compression, cutting and tensile strength, and shear pressure. Insurmountable practical difficulties have been encountered in applying these methods due to the complex rheological
behaviour of foods. Crispness or brittleness associated with certain food products present such instances of relevant examples. Further research needs to be directed at evolving instrumental methods for texture analysis that would permit elucidation of these parameters in a more fundamental sense.

6. ROLE IN PRODUCT DEVELOPMENT

Dairy Industry has traditionally relied heavily on SE techniques for R&D on new product / process development. They can be employed to confirm intentional or unintentional changes in the product or ingredient formulation, identify areas for improvement, determination of process parameters, evaluate competitive products, observe shelf-life behaviour and to substantiate advertising claims. Furthermore, consumer preferences in the regional / ethnic context can also be evaluated. Mainly three SE techniques are employed in this regard, viz., discriminative, descriptive and affective.

Discriminative tests seek either to establish differences among samples (difference test) or measure the ability of the panellists to detect a sensory characteristic. Descriptive tests are designed to identify and quantify sensory characteristics. Various food attributes are rated on a category scale. It is imperative that judges for such tests must have acuity to deal analytically and requisite training. Affective tests are those which are employed to measure preference for a product. These can be either paired preference test between two products or ranking test in which three or more samples are ranked according to preference. Once the data from sensory tests has been obtained, results must be statistically analysed to determine whether significant differences exist in preference. In this manner SE is an indispensable tool in product development for the optimisation of product quality.

7.0 ROLE IN QUALITY MANAGEMENT

In practice, SE is a very valuable tool for grading the quality of raw materials, semi-finished products and final products. Both instrumental and sensory methods are used in a complementary manner for this purpose. Instrumental methods do not guarantee an organoleptic match on one hand and their sensory inequalities on the other, testify to these findings. Sensory panels are less sensitive to detect compositional changes compared to the instrumental methods. Even if samples match previously established standards instrumentally, a rejection is still possible on an organoleptic basis. Conversely, if SE yields acceptable results but compositional variation exceeds the standard values, rejection is automatic. Perceived odour and taste originating from stimulation of sensory cells provide compelling reasons for correlating instrumental and sensory flavour data. If one can derive mathematical models which adequately describe these relations in qualitative and quantitative terms, these models will help explain the mechanisms of stimulation and perception and thus be of help in physiological and psychological research. From a practical point of view, the models may be used in such a way as to complement or supplement with instrumental methods in routine quality control.

8. ROLE IN INTERNATIONAL TRADE

Milk and milk products feature prominently in economy of many countries, such as New Zealand, Australia, USA. Available statistics of world production of milk and milk
products indicate that 11% of butter, 7% of cheese, 26% of skim milk powder and 47% of the whole milk powder enter the international trade. Changes in the national policies towards subsidies during the post-GATT period would necessitate European Union would have to cut down milk production by about 2 MT towards the end of 2000 AD. While at the same time the market demand for whole milk powder and cheese in the EU would go up by 5 MT milk equivalent. Better access would be available to high price markets of the world. In the international trade of milk and milk products, it becomes imperative to define the standards of acceptance/rejection on quantitative basis between exporting and importing countries. In most instances, it is not practical to carry out pre-despatch inspection, because of the distances involved between importing and exporting countries. For certain major commodities of international trade, such as Cheddar cheese, the product profile is rather complex to quantify. The methods of tests should be quantitative as well as reproducible, but not limited by human 'error' as in the case of subjective tests. Furthermore, variations in the terminology and methods of tests between exporting and importing countries pose a major impediment to the international trade practices. For bringing about uniformity at the International level in the use of terminology and methods for SE of Dairy Products, a Task Group (D6) has been established by the Commission on Legislation, Standards of Identity, Classification and Terminology under the auspices of International Dairy Federation. Further research is under progress to standardise/correlate the Rheological parameters in conjunction with characterisation of Microstructure of dairy products so as to provided commercial terms of reference for product quality and thus pave way for promotion of international trade.

9. SUMMARY

Sensory Evaluation and rheological measurement are indispensable tools for product process development in the Dairy Industry the world over. Although subjective measurements provide probably the only way to obtain meaningful information about the food quality, it is often difficult to develop well defined product profile reference for industrial quality assurance, and international trade, specially when importing and exporting countries are distantly located. In turn, objective tests present difficulties in defining correlation with subjective quality. Multidimensional analysis is necessary for both subjective perceptions and objective characteristics of the food.

SUGGESTED READINGS


II. BASICS OF SENSORY EVALUATION OF FOODS
ROLE OF PRIMARY SENSES IN SENSORY EVALUATION

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1. INTRODUCTION

The senses of smell and taste have always been used for guidance in our selection of food and beverages. The ability to discriminate between desirable and undesirable foods is apparently as old as the human race. During the past 20 years attention has been focused on the palatability of dairy products with particular research effort directed towards improvement and stability of dairy products. The research is giving significant impetus to the evaluation and grading of dairy products. Ever since this country has become self-sufficient in milk and milk products various brands and trade names of dairy products have been established, particularly for infant and malted foods, butter and ghee and even processed cheese. This development necessitated recognition of set standards of quality by the manufacturer and the subsequent need for grading of finished product (Agmark, ISI etc.). Products such as Lactogen, Amul, Vijaya have become well known.

While dairy products can be analysed for chemical composition, microbes, vitamin content, enzymatic activity, colour, physical properties etc. these determinations are often inadequate. The senses of smell and taste have always been used for guidance in our selection of food and beverages. The ability to discriminate between desirable and undesirable foods is apparently as old as the human race. During the past 20 years attention has been focused on the palatability of dairy products with particular research effort directed towards improvement and stability of dairy products. This research is giving significant impetus to the evaluation and grading of dairy products. Ever do not preserve the "true" or actual EATING QUALITY of a product. Two samples of butter may have identical chemical composition, colour, firmness and spreadability, however, one sample may be highly relished by the consumer, while the other product may leave a poor impression. A dairy food that is liked or preferred by a majority of consumers is considered to have good EATING QUALITY. Butter of good to excellent quality generally conveys the impression of being clean, creamy, aromatic in flavour and seems distinctly fresh and appetising whereas the sample that left a poor impression may be stale, rancid, oxidised, fishy or may have some other objectionable off-flavour.

Establishing the eating quality of a dairy product requires the application and CORRECT interpretation of such sensations as mouthfeel, taste and smell. These are felt in the mouth.

2. PRINCIPLES OF SENSORY PERCEPTION

The evaluation of dairy products for flavour is primarily a matter of noting carefully and interpreting correctly a set of sensory reactions after each product is sampled. The ability to critically evaluate dairy products can be learned, if close attention is directed to the delicate
senses of smell, taste, touch and sight which practically every one is endowed. It is composed of taste and odour. Hold the nose or even hold the breath, the flavour vanishes; breathe again and it reappears at once. Of the other qualities, texture is the most important. Smoothness or roughness, particle size, solubility, even glutinous quality can modify flavour. Less usual modifiers of flavour are hotness of spices such as ginger, the coolness of menthol.

2.1 The human senses

Psychologists recognise 22 special senses (or subdivisions) in human beings. Humans supposedly possess 5 primary senses for perceiving stimuli. They are SIGHT, HEARING, TOUCH, SMELL and TASTE. The last two are considered most primitive. Other senses include temperature, pain, visceral hunger, thirst and fatigue, sex (drive), equilibrium.

At least 3 different senses respond to specific chemical stimuli: Taste, smell and so-called common chemical or pain sense. Humans are primarily sight guided in their search for food whereas other animals, such as dogs and pigs are scent-guided. Within humans, smell has a great complexity of qualities and features.

2.2 Sensory receptors (Table 1)

We experience our environment and many events occurring in our body through specialised sense organs or sensory receptors. These are: EYE, EAR, SKIN each as an organ of touch or pressures, the TONGUE as organ of taste and NOSE as the organ of smell. Each of these organs responds to a particular range of stimuli and transmits the information to the brain via the central nervous system. Up to a point the response of the sensory cells is proportional to the stimulus intensity.

Factors from the environment or from body biochemistry that elicit sensory impressions or perceptions of a certain quality are called SPECIFIC SENSORY STIMULI. The term sensory impression serves experience. The perceived odour GOATY, the taste SALTY, and mouthfeel GRITTY are examples of sensory impressions. Such impressions are seldom perceived in partial or total isolation: a combination of such sensory impressions is called a SENSATION. In most situations, a pure sensation is accompanied by an interpretation with reference to what has been experienced or learned by an individual; the resultant OVERALL IMPRESSION is called a PERCEPTION. We express a perception when we say "This milk is too sweet". Perception has 4 basic dimensions: time, space, quality and intensity (quantity).

3. PHYSIOLOGY OF SMELL AND TASTE

Sensitivity to various chemicals is basic to all human and animal life. The human senses are the means or chemicals of information through which everything we know is received into the consciousness. Chemical sense receptors for humans are primarily in the nose and mouth, but some receptors for pain (chemical) occur in other locations of the body. Receptor sites for these senses respond to chemical stimuli or the arrival of chemical particles. This is in direct contrast to the PHYSICAL senses of sight, hearing, touch and temperature which respond to physical stimuli.
The sense of smell is substantially more refined than the sense of taste. A typical person requires relatively concentrated solution in order to perceive taste sensation. By contrast, an odoriferous substance e.g., MERCAPTAN may be diluted to the extent of 0.43 x 10 to the power minus 15 mg/l of air and yet be recognised as such by the sense of smell. The human sense of smell is by far more sensitive than any other chemical procedure or equipment devised so far.

3.1 Odour receptors

Somewhere in our anatomical equipment there is a device that sorts out thousands of different kinds of odours and enables us to distinguish one flavour from the other and even detects slight off-flavours. The olfactory receptors are located in the roof of the nasal cavity and is lined with so-called olfactory epithelium which is yellowish in colour with pink respiratory epithelial cells around it. The surface of the olfactory epithelium is coated with a layer of mucous. Embedded in the mucous layer is a mat of fine hair-like appendages of the olfactory cells called CILIA.
3.2 Odour perception

In order to perceive the odour of a chemical substance the chemical must be VOLATILE. The volatility of a substance depends on its molecular weight and molecular bonding properties. The upper limit of a SMELLABILITTY is usually a molecular weight of about 300, although a compound of MW 394 has odour. This suggests that heavier MW substances such as protein, starches, fats and many sugars are too heavy to be airborne under most circumstances. While molecular bonds vary with chemical compounds and temperature, more volatile molecules are derived from liquids than from solids but the volatility of both states matter increases with increase in temperature. Odoriferous substances must be absorbed or adhered to the chemoreceptor sites in the nose. To be absorbed, a volatile substance must be soluble to some extent in the receptor cell membrane which consists of lipids, proteins and water. Most volatile organic compounds are soluble to some extent in the membrane constituents.

3.3 Taste receptors

Taste receptors are groups of sensory epithelial cells enervated (stimulated) by sensory nerve endings. The taste receptors look like flower buds, hence are termed TASTE BUDS. Human taste buds are located on moist surfaces within the oral cavity and pharynx (see ). The tongue serves as the major organ of taste. The taste bud sites are in the epithelium of the tip, lateral and dorsal surfaces where they are generally associated with certain papillae.

FUNGIFORM papillae on the anterior tongue segment and FOLIATE and VALLATE papillae on the posterior part. A few nonpapillae associated taste buds may be found in such locations as the SOFT PALATE, PHARYNX and LARYNX. These taste buds are simply embedded within the epithelium of the mucous membrane. The stimulation of taste buds is derived from the SENSORY component of 3 different cranial nerves: FACIAL, GLOSSOPHARYNGEAL and VAGUS. The facial nerve enervates the taste buds in the anterior of tongue and soft palate. The GLOSSOPHARYNGEAL and vagus nerves accommodate sensory enervation of all the remaining taste buds.

3.4 Taste perception

The taste buds, with which the sapid substances (in liquid form) must make contact before a taste sensation occurs, are located in many of these papilla at the tip, sides and the base of the tongue. They differ somewhat in their response to stimuli. The SOUR taste may be noted chiefly of the tongue. ALONG the sides SALTINESS along the Sides and tip, SWEETNESS generally at the Tip, and BITTER taste at the BASE of the tongue.

4. THE CONCEPT OF FLAVOUR

Odour and taste combined with mouthfeel result in overall concept of sensation referred to as ‘FLAVOUR’. Flavour has been defined as the sum total of the sensory impressions (sensations) perceived when a food or beverage is placed into the mouth.
Role of human senses

Flavour is the sense of foods and beverages.

It is composed of taste and odour. Hold the nose or even hold the breath, the flavour vanishes; breathe again it reappears at once. Of the other qualities, are cernated (excited) by molecules of odoriferous substances. Since this area of smell is reached chiefly by EDDY CURRENTS rather than the direct passage of air during inhalation, the odoriferous substances must be SNIFFED or WHIFFED rather slowly but strongly while respiration is slowed or stopped. During exhalation there is no appreciable smell sensation.

Smell sensation may also be perceived by diffusion, however, this is very slow and in any case when breath is held no odour sensation is noted. Hence the evaluator must draw a full breath of air through the nose rather positively and prolongedly. Experienced tasters realise that during food mastication odours may be noted without consciously smelling the product. During mastication molecules of aromatic substances pass to the olfactory area from the mouth. During the tasting of dairy products the evaluator is actually sensing odours) and tastes of the product simultaneously. It is believed that during tasting, gentle exhalation through the nose is beneficial because it serves to force volatile molecules toward the olfactory epithelium.

For this reason a food or beverage sample being tasted should be manipulated about the mouth and rolled over the tongue to permit direct contact between the taste buds and sapid substances. The first requirement for tasting a substance is water solubility of the food item. The 2 most primitive tastes: SALT and SOUR show good correlation with molecular structure. The slower response SWEET and BITTER tastes are less related to chemical formulation.

Practically all acids exhibit sour taste. Common salt NaCl and other similar compounds taste salty. However, as the constituent atoms of salts become larger (higher atomic weight) a bitter taste tends to accompany the initial salty taste. Sweetness is characteristics of sugars and is related to the possession of hydroxyl (OH) groups. Bitterness is not easily associated with any structural property.

Truly many different flavours are sensed instead of tasted e.g., PEPPER, PEPPERMINT but these are composite of taste, smell and touch and not true tastes per se. Other feelings in the mouth such as the common chemical or pain sense, warmth, coolness, astringency, smoothness, numbness (anaesthesia) and other feelings noticed during tasting are not taste reactions but sensations of touch or pressure (tactile).

The true tastes may be sensed with the nose obstructed. In fact when a person has cold, the taste reactions, aside from the particular feel of the food in the mouth are sometimes the only components of flavour detected by the individual.

5. CLASSIFICATION OF TASTES AND ODOURS

Strictly speaking we experience only 4 TRUE tastes: BITTER, SWEET, SOUR and SALTY. However, there may be several other taste reactions: ALKALINE, METALLIC, WATERY and/or MEATY. These may be tactual sensations and not true tastes.
Common experience indicates that the number of perceived odours are many and varied. Several investigators have tried to categorise the many odours. Henning in 1916 categorised them into 6 groups. Crocker & Henderson in 1927 simplified the group of 6 into 4, arranged in order of preference by most subjects as shown below.

**Henning**

1. *Spicy*: cloves, cinnamon, fennel, anise
2. *Flowery*: heliotrope, geranium
3. *Fruity*: oil of orange, apple, citronella
4. *Resinous*: balsamic, turpentine, eucalyptus oil
5. *Burnt*: pyridine, tar

**Crocker & Henderson**

1. *Fragrant or sweet*
2. *Acid or sour*
3. *Burnt*
4. *Caprylic or goaty*

Crocker and Henderson - Recognising that any odour stimulates specific receptors for these odours they set up standards for many odoriferous substances based upon the correct quantitative mixtures of the fundamental odours. With a range of intensity of stimuli for each of the 4 basic odours numbered from 0 to 8, they reproduced odours simply by mixing certain intensities of the basic odours. Within this format, any given aromatic substances may contain all 4 fundamental odours (fragrant, acid, burnt or caprylic); their relative degrees of stimulation determines the individuality of that odour. For example, 3803 and 6423 represent the 4-digit symbols for acetic acid and rose odours, as detailed below:

<table>
<thead>
<tr>
<th>Fundamental odour</th>
<th>Acetic acid</th>
<th>Rose smell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fragrant</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Acid</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Burnt</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Caprylic</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

6. ROLE OF OTHER SENSES IN SENSORY EVALUATION

The senses: SIGHT, TOUCH and SOUND are also used in the sensory evaluation of dairy products.

6.1 Sight

Some desirable qualities and some defects of dairy products can be ascertained by careful visual observation. Factors that can be evaluated by the sight are style, neatness and cleanliness of package exterior, attractiveness of product finish, package closures, body and texture, colour and overall appearance, meltdown characteristics (ice cream and other items
that determine quality. Colour and appearance aspect of dairy products should not be overlooked because these features may render the product acceptable/unacceptable.

An experienced judge closely examines each product in an attempt to correlate possible deficiencies in visible items with flavour quality. A soiled butter packaging or an unattractive or a carelessly packaged carton can be readily evaluated by the sight and may furnish the judge with a possible clue to flavour quality. If there is carelessness in workmanship the judge should use smell and taste to detect quality defects. For example if the colour of butter is mottled then the sample should be tasted with alertness for possible defect in flavour. Of course far greater concentration is required to detect defects in samples which show no apparent visual defects.

6.2 Touch

Touch or mouth feel plays an important role in texture evaluation. The tongue and palate evaluate feeling of mealiness or grassy (salty) butter or sandy defect in ice-cream where pressure between the teeth determines the presence of crystallised lactose. The briny defect in butter due to undissolved salt or mealy/grainy in Cheddar cheese are also perceived by the sense of touch. The fingers and thumb also help substantiate the findings of the tongue, roof, and other surfaces of the mouth.

6.3 Sound

The judge can detect the relative size and distribution of holes in Swiss cheese by the gentle tapping of the outside of the cheese. The relative amount of free water in leaky butter can also be determined. When the plug is reinserted into the hole from which it is drawn and noticing the 'slushing sound' made by the moisture inside.
1. INTRODUCTION

A successful implementation of sensory evaluation programme requires three major components viz.; Proper laboratory facilities, sensory panels and rigorous training programmes.

2. LABORATORY SET UP AND EQUIPMENT

The sensory laboratory set up normally consists of a reception cum briefing room, panel booths and preparation room. Sensory evaluation should be conducted in quiet and well lit rooms free from any odours. The dominant motive of constructional details should be to have comfort for concentrated prolonged testing and ease of cleaning. Pleasing neutral shades and maintenance of comfortable temperature and humidity conditions of the whole area or at least the panel room are desirable. The testing area where booths are located should be separated from sample preparation room and wash room and store by a complete partition.

2.1 Reception and briefing room

It should be so designed as to ensure maintenance of pleasant attitudes and minimise traffic to the booths. Panel members shall assemble here, register, receive the evaluation card and briefed about the test.

2.2 Panel booths

These booths should be located between or adjacent to the reception and preparation rooms, and should consist of test booths or identical design. Each booth may be 75 to 80 cm wide having adequate space to keep samples, drinking water, receptacle and writing space. It shall be separated by partitions to screen one person from the view of other when they are seated. Revolving stool with back support or chairs should be provided with drinking water, cleansing towels and glasses and basins for convenient and non embracing expectoration's. The lighting of booths shall be uniform and glarefree and arrangement should be made to provide white or coloured light. A temperature of about 20 °C and RH of 62% in the testing room is considered to be ideal. The entry and exit to the panel booth area by independent doors may be useful to avoid any communication between panel members.
2.3 Preparation room

It shall be suitably separated from the testing room and should be equipped for preparing and serving food samples. The room should have the facility for cooking range hot and cold storage cabinets. The ventilation should be proper and the cooking odours should not penetrate the panel booth area. The samples shall be passed to the test booths through hatch in the partition. The hatch on the service counter should preferably be constructed in such a manner that there shall be no recognition of individual or either side of partition.

The laboratory facility should be flexible enough to handle current and future testing activities, as well as to provide a workable environment for the staff. The use of computers has been recommended for sensory evaluation work. In that case, sensory evaluation laboratory should include space for data processing equipment.

3. SAMPLING REQUIREMENTS

a. Sampling should be carried out by a trained and experienced person and it is essential that the sample should be representative of the lot.

b. A procedure of sample preparation which is most likely to bring out the difference in the particular quality attribute under evaluation shall be selected. Care shall be taken that no loss of flavour occurs and no foreign tastes or odours are imported by the procedure during preparation, storage, serving, etc. Depending upon the nature of the material and aim of the test, the need for a medium in testing auxiliary items should be decided. Foods like hot sauce, spices, vinegar, etc. may require dilution with some medium because of their intense physiological efforts.

c. The panellist should be allowed to have sufficient sample necessary to make judgement. Unless, only one sample is to be tested, full normal serving quantities shall not be served even though the material is available.

d. The temperature of serving should be close to that recommended for the food product. The samples shall be served in utensils of the same type and appropriate size, shape and colour and they shall not import any taste or odour to the sample. The test should be carried out at least one hour before or after lunch.

e. Use of materials which are likely to vitiate results, such as smoking, chewing pan (betel-vine) and taking intoxicants by a panellist should have a time lapse of at least half an hour before the test. Use of strong odoriferous substances such as cosmetics, flowers, hair oil should be avoided.

f. The number of samples served in any one session shall depend upon the nature of the test product and upon the evaluation method used. In case the test product exert mild sensory effects, large number of the products exerting strong prolonged sensory effects, the number of samples may be reduced to less than 5.
g. Since coding is necessary to obscure the identity of the sample, a multiple digit code generated from a table of random numbers should be used. Avoid constant use of certain codes or a set of codes to expedite tabulation of results.

4. EVALUATION CARD

The evaluation card should be clearly printed and the matter should be arranged in logical sequence for examination which is expected under each test. Appropriate terminology without ambiguity shall be used. The evaluation card should be simple, brief, easy to follow and record what is exactly required. Due weightage should be given to all the sensory attributes.

SELECTED REFERENCES

1. INTRODUCTION

Threshold is the point on the stimulus scale where a transition occurs in sensation. Threshold tests are used for determining the minimum detectable levels of concentration of stimuli....

Measurement of thresholds is the most common procedure for studying the psychophysics of taste. Threshold tests are used for the following purposes:

a. Selection of sensory panel of homogeneous sensitivity

b. Understanding the synergistic and autogonistic effect of odour or taste compounds.

c. Quality assurance for prescribing minimum for acceptance through dilution technique.

d. Establishing a correlation between concentration of stimuli and response.

2. TYPES OF THRESHOLD

There are three types of threshold:

a. Absolute thresholds (or better absolute limen) is the minimum detectable concentration. It is that lowest concentration which records a perceivable difference from the blank sample, as determined by the maximum likelihood criterion. It is also called as sensitivity threshold.

b. Recognition threshold is the concentration at which the specific taste can first be recognized and is higher than the sensitivity threshold concentration.

c. Terminal threshold is that magnitude of stimulus above which there is no increase in perceived intensity of the quality of stimulus. Normally pain occurs above this concentration.

3. TASTE THRESHOLDS

Thousands of taste thresholds are reported in literature. The thresholds are generally expressed in percent and in moles. Table 1 shows the average taste threshold of some common compounds for persons of different age groups.
Table 1. Taste threshold values (%) of different age group

<table>
<thead>
<tr>
<th></th>
<th>15-29</th>
<th>30-44</th>
<th>45-59</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taste quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Glucose</td>
<td>0.540</td>
<td>0.522</td>
<td>0.604</td>
</tr>
<tr>
<td>Chloride</td>
<td>0.071</td>
<td>0.091</td>
<td>0.110</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>0.0022</td>
<td>0.0017</td>
<td>0.0021</td>
</tr>
<tr>
<td>Quinine Sulphate</td>
<td>0.000321</td>
<td>0.000267</td>
<td>0.000389</td>
</tr>
</tbody>
</table>

The taste thresholds are affected by several factors. There are: technique employed, impurities in the chemicals, in adequate number of tests or insufficient statistical analysis of their validity and the effect of undetermined factors such as order of presentation, temperature extraneous noise, time of day, experience physical condition, age, sex and area stimulated. Even from day to day using the same subject and method, there are variations in the taste threshold of a given compound.

4. DETERMINATION OF THRESHOLD

Gregson (1962) used a rating scale method for determination of taste threshold. The scale is as follows:

<table>
<thead>
<tr>
<th>Taste reaction</th>
<th>Score integer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same as water</td>
<td>...1</td>
</tr>
<tr>
<td>Doubtful if pure water</td>
<td>...2</td>
</tr>
<tr>
<td>A very faint taste</td>
<td>...3</td>
</tr>
<tr>
<td>Cannot say wheat</td>
<td>...4</td>
</tr>
<tr>
<td>Sweet or other taste</td>
<td>...5</td>
</tr>
<tr>
<td>A weak sour taste</td>
<td>...6</td>
</tr>
<tr>
<td>A clear sour taste</td>
<td>...7</td>
</tr>
</tbody>
</table>

He considered the recognition threshold to be the concentration with a score equal to or greater than 4. The taste solutions of different concentrations are prepared and served to the screened persons for determining their taste threshold. In this way, the individual as well as group threshold can be determined.

REFERENCES

1. INTRODUCTION

Foods are submitted for sensory evaluation to provide information in relation to:

a. that can lead to product improvement,
b. quality maintenance,
c. development of new products, and
d. market analysis.

Tests may be conducted to:

a. select qualified judges and study human perception of food attributes,
b. correlate sensory with chemical and physical measurements,
c. study processing effects, maintain quality, evaluate raw materials, establish storage
stability or reduce cost,
d. evaluate quality, or
e. determine consumer preference.

In general, Lab panels are used for first the 3rd, highly trained experts for the 4th,
and large Consumer groups for the 5th.

There are two types of Lab panels:

a. those which determine simple differences between treated samples, and
b. those which determine directional differences.

2. TESTS USEFUL IN PANEL SELECTION

2.1 Difference tests

The common true difference tests are referred to as single stimulus, paired stimuli,
duo-trio, triangle and multi-sample tests. In tests which do not reveal statistically significant
differences between treatments, no further evaluation is needed. When differences are
found, directional difference tests are used to establish the nature and magnitude of
difference. After a significant difference has been established by a lab panel, consumers may
be asked to express preference.

Except for consumer studies, SINGLE sample is not used. In fact, in products such
as wines, beer, tea, coffee and dairy products several samples are tested and compared, with
previous established standard (MEMORY STANDARD). Occasionally a method called A is
not A, is used, in which a standard A is presented first followed by one or more coded samples. This is classified as PAIRED comparison.

In PAIRED-STIMULI, judges simply specify whether there is a difference between two samples. This procedure is used for comparing new with old processing procedures in quality control and in preference testing at the consumer level.

The DUO-TRIO is modified paired presentation in which one sample and is presented first, followed by two coded samples one of which is identical with the standard. The judge has to identify which of the two is identical to the standard. This procedure is used in quality control and for selection of judges of superior discrimination.

In TRIANGLE test two identical and one different samples are presented simultaneously and the judge is asked to indicate the odd sample. Chance right is 1/3. Like duo-trio test, triangle test is also used to select judges.

2.2 Rank order

Ranking is used to determine how several samples differ on the basis of a single characteristic. A group of coded samples (which may contain a standard) are presented and the judge is asked to rank them in order of intensity of a specified characteristic. This method is suitable for comparing sensitivity of panellists. It can also be used by lab judges in R & D work, by experts for selecting the best sample and by consumer panels for relative acceptability.

2.3 Other methods

Several other tests/procedures including scoring, hedonic rating and acceptance or preference tests, dilution tests, threshold tests etc. can be used in panel selection depending on the objective of the panel testing. These are well established tests and will be discussed in detail in a later lecture.

3. PANEL SELECTION AND TESTING ENVIRONMENT

Analysis of sensory properties of foods involves the use of human subjects in the lab environment. The sensitivity and reproducibility of the judge influences the validity of results. The environment under which the data has been obtained also influences the results.

3.1 Panel selection

By selecting the most stable and sensitive members and training them, one might expect to obtain a small but efficient panel. Selection is important since individuals differ in sensitivity, interest, motivation and ability to judge differences. Discriminating skills may not be general; a good wine taster may not be a good judge of chocolates. Seldom is a judge equally proficient in tasting all qualities and all flavours of foods. The skill of connoisseur has been attributed to knowledge of what signs to look for and how to interpret them rather than increased sensitivity to stimuli. Any method of selection should include a preliminary training period designed to acquaint the tasters with the quality factor involved in the product to be
tested. This should be followed by blind test designed to show the individuals relative perception and discrimination.

3.1.1 Screening

Some type of screening process is required for selecting panel members including specific tests based on:

i) discriminating differences between solutions or substances of known chemical composition,
ii) ability to recognise flavours and odours,
iii) performance in comparison with other panel members, or
iv) ability to discriminate different samples to be used later in the test.

A general approach in screening may be:

i) use as test materials the same products which will be tested later
ii). prepare samples with variations that are likely to be encountered later
iii). adjust the deficiencies so that most will be able to discriminate but some will fail
iv) use score card similar to the ones that will be used later
v) start with a large number of candidates, with simple selection test
vi) screen on the basis of relative achievement continuing until top ranking group of the desired size is reliably selected
vii) reject at each stage those that are not reliable but select more than actually needed

A person with previous experience might utilise some of the skills he has developed. He may be able to note and detect differences which are not detected by inexperienced judges. He can often describe the sensory impressions more fully and usually has a better understanding of the terminology employed.

3.1.2 Sensitivity tests

For general panel selection the candidates can be eliminated on the basis of lack of sensitivity to the senses, attributes, because of poor memory, slow recovery from stimulation and failure to understand the test. Sensitivity to taste or odour appears to be only one of the factors influencing discrimination. In most cases, elaborate tests based on acuity seem unnecessary since absolute sensitivity to the basic tastes is not closely related to perceptual skills.

3.1.3 Factors influencing sensitivity

Important factors in successful judging are interest, motivation, knowledge and comparison of results, adjustment to the test situation memory etc. The panel members should be given as much information as possible on the purpose and need of investigation—however when this information might influence his judgement it should be withheld. A rewards system for maintaining interest is frequently recommended. This may take the form of special pay, time off, special privileges, providing refreshments after panel sessions etc.
3.1.4 Panel size

The number of judges needed will vary according to the variability's of individuals and of the product. For different testing with trained lab judges the panel should consist of 10 to 20 persons with at least 3 or 4 replications per judge per treatment. In order to achieve greater control of the panel, it is possible that 10 judges are better than 20. EXPERT panels of 5 to 10 are satisfactory. Consumer types tests require >80. Institute of Food technologists (USA) recommends 3 to 10 for TRAINED; 8 - 25 for SEMI-TRAINED and 80 + for UN-TRAINED.

3.2 Training

Training should be distinguished from experience. Training steps which may be taken deliberately to increase the effectiveness and the rate at which the individual assimilates new knowledge or new techniques. Training is directed towards getting panel members to disregard their personal preferences. It might also be directed— to secure recognition of small differences. One of the important aims of training is to obtain homogeneity of response. Sensitivity to basic tastes and odours increases due to training. Training helps judges learn to compare flavours and flavour strengths in spite of time lag between samples.

3.3 Environment

Control of environment factors and samples is universally recognised for sensory evaluation of foods. Interpretations and distractions should be avoided during testing. Regularity, quietness, comfortable surroundings, orderliness and smoothness of presentation of samples are important. Judges should record their results independently and should not be able to communicate their impressions to those entering the lab later either verbally or through facial expressions. The lab should be air-conditioned, well lighted, comfortable seating and free from distractions/smoking and cosmetic odours. Judges should be provided comfortable seating, a separate receptacle for expectoration, water for oral rinsing and adequate space for the samples and score card. The facilities should be thoroughly cleaned after the judge leaves and the new one comes.

3.4 Time of the day

Tests should be arranged when the judges feel their best. Generally a time of 10:15 to 11:45 AM and 3:00 PM have been recommended. At these times the influence of breakfast has passed but the subject is not hungry yet. No significance differences have been observed when the tests were conducted at 11 AM or 3 PM.

3.5 Sample factors

Foods differ from each other in intensity or quality levels and these may influence the conduct of tests. However, this is not much applicable to dairy products which have very mild delicate flavours. If interest can be maintained, panel members can evaluate rather large number of samples per session particularly with bland or mild flavoured food. Normally the number of samples should be restricted to 6.
3.6 Masking

Masking refers to intentional minimising of colour, taste or odour properties so that the differences between samples can be evaluated with less interference from the variable which has been minimised i.e., use coloured containers, coloured light etc.

3.7 Preparation

It is pertinent to discuss proper preparation of food, cooking procedures, methods of detecting flavour pick up and the standards used. The normal procedure is to test the food under conditions approximately the same as found under normal consumption: bread should be dry, butter solid, vegetables whole etc. Within a set of samples, the standard should also be presented as an unknown.

4. SERVING PROCEDURES

The samples presented must be exactly alike. Among the factors to be considered are visual appearance, sample size, temperature, utensils, pouring, coding, order, instructions and rinsing. The ability to taste may be affected by substances prior to flavour evaluation.

4.1 Appearance

The samples should be the same in form, consistency, colour and appearance.

4.2 Sample size

Judges should be provided with sufficient sample to taste with confidence. Sufficient sample to give a feeling of MOUTHFULNESS is recommended i.e. 30 to 50 ml, sufficient for 2 mouthfuls.

4.3 Temperature

Uniformity of temperature is necessary. Milk should be served at 15°C.

4.4 Utensils

All samples should be served in the containers of the same size, shape and colour. The utensils should not impart a taste or odour to the samples. Many detergents leave an odour (since they are perfumed) unless the utensil is thoroughly rinsed. Samples should be placed in the container in a uniform/aesthetic manner.

4.5 Coding

All samples presented should be coded to avoid giving information to the panel. Three digit random numbers are ideal.
4.6 Order of serving

While some investigators have found no effect from order of serving, but usually the first sample is assumed to be standard against which the rest of the samples are rated. Ideally strong flavoured samples should be served last as they frequently over-sensitize the taste buds and recovery is not quick.

5. INSTRUCTIONS TO JUDGES

It may not be necessary to give instructions to a trained panel but this is not true for all panels. Questions arise as to method of swirling the glass, chewing, smelling, to swallow or not, how many samples to warm up, to rinse between tastings or not and the time allowed for each of these. The best practice seems to be to allow the judges to use his preferred method but the same technique should be used by him.

6. SUMMARY

Careful selection of judges is essential to achieve maximum discriminability. Least sensitive judges should be eliminated. The influence of health, age, sex, and smoking on panel performance does not seem critical. However, emotional factors, interest, motivation, knowledge, comparison of results, adjustment to test situation and memory do seem to influence results. Environment needs to be controlled, mid-morning is ideal for sensory evaluation.
1. INTRODUCTION

Sensory tests are conducted to meet the following purposes

- Select qualified judges and study human perception of food attributes
- Correlate sensory with chemical and physical measurement
- Study processing effects, maintain quality, evaluate raw material selection, establish storage stability or reduce costs
- Evaluate quality or
- Determine consumer reaction

Each of these purposes requires appropriate tests. There are a substantial number of test methods and new methods continue to be developed. Stone and Sidel (1993) have classified these methods into following three broad categories:

<table>
<thead>
<tr>
<th>Category</th>
<th>Test Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discriminative</td>
<td>Difference: paired comparison, duo trio, triangle</td>
</tr>
<tr>
<td>Descriptive</td>
<td>Descriptive analysis: Flavour and texture profile, QDA</td>
</tr>
<tr>
<td>Affective</td>
<td>Acceptance preference: 9 point hedonic</td>
</tr>
</tbody>
</table>

2. DISCRIMINATIVE TESTING

This is one of the most useful analytical tools available to the sensory professionals. It is on the basis of a perceived difference between two products that one can justify proceeding to a descriptive test in order to identify the basis for the difference. Within this general class are a variety of specific methods e.g.

- Paired comparison test
- Duo-trio test
- Triangle test
- Multiple sample test
- Other test methods such as dual and multiple standard test.

The main objective of all these methods is to answer a simple question, "Are the products perceived as different"? Obviously the response to this question can have major consequences. If the conclusions from a discrimination test are to be accepted by management as reliable, valid and believable, then it is important that each test be conducted
with proper consideration for all aspects of the test design, product preparation and handling, implementation, data analysis and interpretation.

2.1 Paired comparison test

The paired comparison procedure is the earliest example of the application of discrimination testing to food and beverage evaluation. It has also been used successfully for determinations of threshold for basic taste solutions. The paired comparison test is a two product test, and the panellist task is to indicate the one that has more of a designated characteristic such as sweetness, tenderness or skininess. This method is also identified as a directional paired comparison test, the "directional" component altering the panellist to a specific type of paired test. The paired comparison test is relatively easy to organize and to implement. The two coded products (AA, BB, AB, BA) are served simultaneously and the subject has to decide whether "there is difference" or "there is no difference". Requiring a "difference" response in all cases has been found to give better results.

Another version of the paired test is the A-not-A procedure. The subject is presented with a single sample for evaluation, which is then replaced by a second sample. The subject then makes a decision as to whether the product are the same (or different). This particular test procedure has considerable merit in those situations where non test variables such as a colour difference may influence results.

2.2 Duo-trio and triangle test

These tests have been discussed earlier. The Duo-trio test is suitable for products that have relatively intense taste, odour and / or kinaesthetic effects such that the sensitivity is significantly reduced. It lends itself to use for quality control and for selection of judges for superior discrimination. The chance probability associated with the duo-trio test is identical with that of the other two product tests. Whenever products are being compared with a current franchise (i.e. product now being manufactured), the duo-trio, constant-reference test method, is most appropriate.

The chance probability associated with the three product (triangle) test is only 1/3, which accounts for its claim of greater sensitivity. The triangle test is a more difficult test because the subject must recall the sensory characteristics of two products before evaluating a third and then making a decision. In fact, the test can be viewed as a combination of three paired tests (A-B, A-C and B-C). Products that have intense flavours and aromas that are spicy and/or are difficult to remove from palate, or that have physiological effects (distilled beverages) usually preclude the use of the triangle test.

2.3 Multiple sample test

Tests involving more than 3 stimuli are classified as multiple sample tests. They may have equal (symmetrical) or unequal (asymmetrical) numbers of each stimulus. When they are applied as true difference tests, the judge is required to separate the samples into two groups or like samples. When they are applied as directional tests, the judge is asked to identify the groups of higher or lower intensity or a given criterion. Difference test designs involving more than three stimuli have had only limited use. The limitation is based on the
increase in psychological complexity and physiological fatigue which accompanies an increase in the number of stimuli. In addition, large quantity of samples are required and more time is needed for the observer to make a decision. These tests appear to be most applicable to visual discrimination where the judge does not rely on memory and fatigue is almost non-existent.

2.4 Dual standard test

The dual standards method was proposed for use in quality control situations. The subject is served four products; two are identified as references A and B and two are coded. The subject must match the reference product with the coded product. The designation of the two references could reflect quality control limits or current production and product outside the limit.

2.5 Multiple standards test

This test was developed for odour evaluation when a non-uniform standard was to be compared with an unknown. Any number of the questionable standards are presented simultaneously with the unknown and the subject is asked to designate the one which is most different. The chance probability of identifying the unknown correctly is ones over the total numbers of samples involved.

The literature provides a somewhat conflicting selection of conclusions regarding the sensitivity of the various test methods; some sensory professionals suggest that the triangle is more sensitive than the duo-trio and the paired tests, while the others have arrived at contrary conclusions. The various difference tests can be ranked in terms of increasing sensitivity as: paired, dual standard, duo-trio, triangle and multiple standard (Amerine et al 1965). Recently Stone and Sidel (1993) have concluded that all discrimination tests are equally sensitive.

3. DESCRIPTIVE ANALYSIS

Descriptive analysis is a sensory methodology that provides quantitative descriptions of products based on the perceptions of a group of qualified subjects. It is a total sensory description taking into account all sensations that are perceived - visual, auditory, olfactory, kinaesthetic, and so on - when the product is evaluated. Descriptive analysis results provide complete sensory descriptions of an array of products and provide a basis for determining those sensory attributes that are important to acceptance. The results enable one to relate specific process variables to specific changes in some of the sensory attributes of a product. From the product development viewpoint, descriptive information is essential in finding out those product variables that are different and from which one can establish cause and effect relationships.

A descriptive test involves relatively few subjects who have been screened. Screening should be product category specific as is the subsequent training effort. Training is primarily focused on development of descriptive language which is used as a basis for scoring the product. Apart from this the other important activities that are part of training include, the grouping of attributes by modality (i.e., appearance attributes, aroma attributes and so on), listening them by occurrence, developing a definition for each attribute, identifying helpful
references for use during training, and familiarising the subjects with the scoring procedure. There are numerous applications for descriptive analysis, including monitoring competition, storage stability/shelf life, product development, quality control, physical/chemical and sensory correlation, etc.

Depending upon the test methods used the training can be quite different. Some of the descriptive methods described in the literature are summarised here.

3.1 Flavour profile

The flavour profile method is the only formal qualitative descriptive procedure and is probably the most well known of sensory test methods. This method utilises a panel of four to six screened and selected subjects who first examine and then discuss the product in an open session. Once agreement is reached on the description of the product the panel leader summarises the results in report form. The method has considerable appeal because results could be obtained rapidly and would obviate the need for statistics.

3.2 Texture profile

This method represents an advancement in descriptive analysis with respect to development of the descriptive terminology, the scales for recording intensities and the word/product anchors for each scale category. In developing the method, the objective was to eliminate problems of subject variability, allow direct comparison of results with known materials and provide a relationship with instrument measures. There is considerable appeal to the direct link between specific instrumental measures of these rheological properties of a product and the responses of a panel of specific sensory attributes, for example, texturometer units and hardness sensory ratings. However, separation of texture from other sensory properties of a product such as colour, aroma, tests and so forth limits the total perception of the product's sensory properties.

3.3 Quantitative descriptive analysis

The quantitative descriptive analysis (QDA) method was developed with an approach that was primarily behavioural in orientation with a consensus approach to language development, use of replication for assessing subject and attribute sensitivity, and for identifying specific product differences and defined statistical analysis. The development of method evolved from a number of considerations to ensure that it would:

- Be responsive to all the sensory properties of a product
- Rely on a limited number of subjects for each test
- Use subjects qualified before participation
- Be able to evaluate multiple product in individual booths
- Use a language development process free from leader influence
- Be quantitative and use a repeated trials design
- Have a useful data analysis system

In a QDA test, the subjects evaluate all of the products on an attribute basis on more than a single occasion.
3.4 Other Methods

Many more descriptive methods have been described in the literature which are more or less on the lines of the test methods discussed above. The spectrum descriptive analysis, for example, involves extensive training activities, reflecting the basic Flavour and Texture Profile procedures, with particular reliance on training the subjects with specific standards of specified intensities. Free choice profiling is another approach in which no subject screening or training are required and the subject can use any words they want to describe the products being evaluated. The time advantage may, however, actually not be there since the experimenter requires to spend time explaining the testing procedures to the subjects.

3.5 Scoring

The most frequently used of all sensory testing systems is scoring because of its diversity, apparent simplicity, and ease of statistical analysis. Scoring methods have most extensively been used by the dairy industry for product development and improvements, shelf life studies and assessing suitability of packaging materials. Score cards based on 100 points are generally used for judging and grading of dairy products. Most recently 25 points score cards have been suggested (Bodyfelt et al, 1988). It is believed that numerical rating tests give more complete information than either ranking tests or descriptive rating tests, but the judges must be trained. Since there is no indication of liking to the test product, palatability norms should be established. The score card must be properly developed giving due weightage to all the sensory attributes.

4. AFFECTIVE TESTING

Acceptance testing, a valuable and necessary component of every sensory programme is performed at consumer's levels. It refers to measuring liking or preference for a product. Preference can be measured directly by comparison of two or more products with each other, that is, which one of the two or more products is preferred. Indirect measurement of preference is achieved by determining which product is scored significantly higher than another product in a multiproduct test, or which product is scored higher than another by significantly more people. The two methods most frequently used to directly measure preference and acceptance are the paired comparison test and the nine point hedonic scale. Other methods are either modifications of these two methods or are types of quality scales: for example, excellent to poor and palatable to unpalatable.

4.1 Hedonic scale

The nine point hedonic scale has been used extensively since its development with a wide variety of products and with considerable success. The scale is easily understood by naive consumers with minimal instruction and the product differences are reproducible with different groups of subjects. The results from use of this scale are most informative since computations will yield means, variance measures and frequency distributions, all by order of presentation and magnitude of difference between products by subject and by panel and the data can be converted to ranks as well, which yields product preferences. An example of the scale is given below:
Like extremely 9,
Like very much 8
Like moderately 7
Like slightly 6
Neither liked nor disliked 5
Dislike slightly 4
Dislike moderately 3
Dislike very much 2
Dislike extremely 1

The subject task is to circle the term that best represents their attitude about the product. The responses are converted to numerical values for computational purposes, e.g., like extremely 9; dislike extremely 1; in a 9-point scheme.

The sensory acceptance test is a very cost-effective resource that has a major role to play in the development of successful product. Properly used, it can have a significant impact on the growth and long term development of sensory evaluation.

REFERENCES

1. INTRODUCTION

The researcher is always interested in drawing conclusions from the ranking which determines the quality of a product. These are usually the problems in which we place things in an order of merit without numerically measuring their intrinsic worth. Sensory evaluation of dairy products is one such area where scores are assigned to different makes of dairy products using different scales based on qualitative characteristics like flavour, colour, body and texture, over all acceptability etc. For example, a judge might rank different makes of ice-cream in the order of preference without committing himself to any indication of how much better one ice cream is than the other. Ranking arises naturally in cases where there is lack of time, money, instruments, or reasonably defined units, measurement of the characteristic being judged is impossible. A number of statistical techniques are available to analyse the data obtained as a result of sensory evaluation.

2. RANKING METHODS

Ranking methods are used where the characteristics are of qualitative nature. Sometimes recourse to these methods is taken even where measurements are made in order to reduce the labour of computation or to get a rapid result. There are several techniques:

2.1 Spearman’s Rank correlation method

The best known technique in this field is Spearman’s Rank Correlation Coefficient. Suppose we have ten makes of ice-cream ranked in order or preference by two judges. The problem is: Do the judges show evidence of agreement among themselves with regard to ranking? In this case we use Spearman’s Rank Correlation Coefficient which is defined by the formula,

\[ R = 1 - \frac{6 \sum d_i^2}{n(n^2-1)} \]

where ‘\(d_i\)’ is the difference between ranks given by two judges for \(i\)th make of ice-cream and \(n\) is the number of makes of ice-cream.

Whenever two rankings are identical, the rank correlation has the value +1 and when the rankings are as greatly in disagreement as possible i.e., when one ranking is exactly the reverse of the other, the rank correlation coefficient is equal to -1. The significance of the rank correlation coefficient is tested through \(t\)-test which is computed by the formula

\[ t = R \sqrt{\frac{n-2}{1-R^2}} \]

distributed as \(t\)-statistic with \((n - 2)\) degrees of freedom. In case of computed \(t\) value being greater than tabulated value of \(t\), it is concluded that there is an
evidence of significant agreement between two judges. This should not be meant as that the two judges are really placing the different makes of ice-cream in the correct order approximately. It is quite possible that though they both agree and they are both wrong.

2.2 Coefficient of Concordance

Very often, as in the case of sensory evaluation of dairy products, we are not concerned simply with the agreement between two judges, but have several judges and want to know whether there is significant measure of agreement among them. In such cases, coefficient of concordance which is a measure of overall agreement among the judges is used. Suppose we have 'n' makes of ice cream being subjected to sensory evaluation by a panel of 'm' judges. Let us suppose that the judges assign rankings to the different makes of ice-cream and it is desired to test whether there is an evidence of overall agreement among the judges. The Coefficient of Concordance as measured by 'w' is defined by the formula,

\[ w = \frac{\frac{3}{2}S_{max} - \frac{125}{m^2(n^2-n)}}{m^2(n^2-n)} \]

where 'Smax' is the maximum possible sum of squares when the judges are in complete agreement and their expectation on the Null Hypothesis that there is no agreement among the judges. 'S' is the sum of squared differences between observed and the expected rank totals.

The Coefficient of Concordance 'w' lies between '0' signifying complete randomness in the allocation of rankings to 1 signifying complete agreement among the judges. 'w' can be tested for significance using Snedecor's F distribution as follows:

**Step 1.** A 'Continuity Correction' is applied whereby subtract unity from the calculated value of 'S' and increase the divisor \( \frac{m^2(n^2-n)}{12} \) by 2 and then calculate 'w'.

**Step 2.** Calculate Snedecor's F as \( F = \frac{(n-1)w}{1-w} \) distributed as F statistic with degrees of freedom \( (n-1) - \frac{2}{m} \) for the greater estimate and \( (m-1)(n-1) - \frac{2}{m} \) degrees of freedom for the lesser estimate.

If calculated value of 'F' statistic is greater than tabulated 'F' then the judges do exhibit a notable degree of agreement in their judgements of the palatability of the different makes of ice-cream from different manufacturers.

2.3 Coefficient of Consistency

Sometimes a question arises whether ranking is a legitimate procedure at all. It can often be the case that we sensibly have a preference for one item over the other without being able to show logical justification for a ranking procedure. In our ice-cream example there are many factors which might influence several judges differently. One judge may be influenced by taste, the other by colour, another by attractive package, and so on. Such type of judgements are called 'multidimensional'. Characteristic of all such cases is inconsistency of judgements expressed by the same observer. The problem of multi-dimensional judgements can be tackled on the basis of paired comparisons, rather than straight ranking. In this case the judge is provided with every possible combination of
two items from the set of items to be evaluated and leave him scope for inconsistent judgements.

In general, given 'n' items, pairs can be chosen in \( n_c_2 \) ways. Here the judge is not allowed to declare himself unable to decide between one item of a pair and another. He has to decide either way.

For example, if we have 7 items (A, B, C, D, E, F and G) to be compared then we have 21 pairs. A table is prepared where we record choice of judges in which the symbol 'I' is allotted if the item denoting the row of the table is preferred to the item denoting the column whereas symbol 'O' is allotted if the item denoting the row of the table is rejected in favour of the item denoting the column. Obviously since no item is compared with itself the diagonal of the table will be blank.

The consistency of the judge is tested by coefficient of consistency which is given as

\[
K = 1 - \frac{24d}{n^3 - n} \quad \text{when 'n' is odd} \\
K = 1 - \frac{12d}{n^3 - 3n} \quad \text{when 'n' is even}
\]

where 'd' is the number of circular triads observed in a given set-up of choices.

The value of \( d \) is given as

\[
d = \frac{T_{\max} - T}{12}
\]

where \( T_{\max} = \frac{n^3 - n}{12} \) and \( T = \sum (S_i - E_i)^2 \) Where

\[
S = \text{sum of the row and 'E' is the expected frequency of the symbol per row and is given by} \left( \frac{n-1}{2} \right) .
\]

The value of 'k' lies between 'O' and 'I'. 'k' attains the value 'I' if there are no inconsistent triads of judgement otherwise it is less than 'I'. Whenever \( k=1 \), we are justified in setting up an ordinary ranking of items but not otherwise.

2.4 Coefficient of Agreement

It may be noted that the existence of significant consistency does not necessarily guarantee that his judgement is sound. A man may well be consistently wrong. Even a group of observers / judges may be consistently and jointly wrong. In such cases, the possible solution is to increase the number of judges doing our paired comparison test. Now the question is whether there is a degree of agreement among the judges. This is carried out by computing Coefficient of Agreement.

Suppose there are 'm' judges doing the paired comparison test. Then in our table of results we can record square by square, the number of judges stating the preference in question. In this way each cell in our table might contain any number from 'm' (when all the judges state the preference A→B) to zero (when all the judges state preference B→A). Given 'n' items to be compared, there will be \( n_c_2 \) paired comparisons. If all the judges are in perfect agreement, there will thus be \( n_c_2 \) cells in our table containing the score 'm', and \( n_c_2 \) cells containing the score 'O'.

The next step is to find the number of agreements between pairs of judges. For example if a particular cell in the table contains the score 'j' to indicate that 'j' judges had agreed in ranking of that particular choice, these 'j' judges could be arranged in \( j_c_2 \) pairs, all
agreeing about the judgement in question. The same calculation has to be repeated for the number of agreements between pairs of judges for every cell in the table getting for each cell a term of the type $j_{ij}$, where $i'$ is the number of judges in various cells. Adding up all these $n$ $j_{ij}$ terms for the whole table we get $J = \sum_{i=1}^{n} j_{ij}$ with 'n' items to be compared. Now with 'm' judges and 'n' items to be compared. The coefficient of agreement is defined by the formula $A = \frac{2J}{m(n-1)} - 1$. The coefficient of agreement lies between -1 signifying complete disagreement between two judges and +1 signifying maximum number of agreements occurring when $n_{ij}$ cells each contain the number 'm', and the maximum number of agreements between judges will be $m_{ij} = n_{ij}$.

The coefficient of agreement can be tested for statistical significance through chi-square test. The expression $Z = \left[ \frac{4J}{m(n-1)} - \frac{m(n-1)}{2} \frac{1}{(n-2)^2} \right]$ is distributed as $\chi^2$ with $\frac{n(n-1) - 2}{2(n-2)}$ degrees of freedom.

3. CHI-SQUARE AS A TEST OF INDEPENDENCE

Many times, the management of a dairy plant wants to know whether the differences they observe among several sample proportions are significant or only due to chance. Suppose the dairy plant manager conducting consumer preference survey for a dairy product wants to know whether the proportion of persons liking the dairy product differs significantly among different age groups / income groups / education groups / food habit groups / regions etc. This is carried out using chi-square test for independence of attributes where the objective is to test whether the two attributes A and B each at 'r' and 's' levels, respectively, possessed by persons are independent. The chi-square formula to test the independence of attributes is given as $\chi^2 = \sum_{i=1}^{r} \sum_{j=1}^{s} \frac{(o_{ij} - e_{ij})^2}{e_{ij}}$ distributed as $\chi^2$ with (r-1)(s-1) degrees of freedom where $(A_iB_j)$ are the number of persons possessing the attribute A at ith level and attribute B at jth level. $(A_i)$ are the number of persons possessing the attribute A at ith level irrespective of the level of attribute i.e., column total and $(B_j)$ are the number of persons possessing the attribute B at jth level irrespective of the level of attribute i.e., row total. N is the total number of persons.

If calculated value of $\chi^2$ is greater than the tabulated $\chi^2$ then we may conclude that the attributes under consideration are not independent which may imply that the liking of dairy product differ significantly among different groups considered in the study.

3.1 Precautions about using chi-square test

- The sample size should be large enough, preferably more than 50.
**Statistical methods**

- No theoretical cell frequency should be less than 5 in one cell of the contingency table. In case of expected cell of frequency being less than 5, combine this frequency with either preceding or succeeding frequency to get an expected frequency of 5 or more. In case of 2x2 contingency table if the cell frequency is less than 5, use Yate's correction which consists in adding 0.5 to cell frequency which is less than 5 and then adjusting the other cell frequencies accordingly.
- Use carefully collected data.

4. **ANALYSIS OF VARIANCE**

Analysis of Variance (ANOVA) is an important statistical technique which enables us to test the significance of the differences among more than two sample means. This technique consists in splitting up the total variation into components of variation due to independent factors where each component gives us the estimate of population variance and the remaining being attributed to random causes of variation.

Analysis of variance is very useful in sensory evaluation studies. Here one can compare average flavour score / body and texture score / overall acceptability score given by a panel of judges among different types of kulfi / ice-cream or any other dairy product prepared with different ingredients varying at different levels. In each of these cases we compare the means of more than two samples.

In order to use Analysis of Variance, it is assumed that each of the samples is drawn from a normal population and that each of these populations have the same variance $\sigma^2$. If, however, the sample sizes are large enough, the assumption of normality is not so crucial.

4.1 One-way Analysis of Variance

Here the researcher wants to test the hypothesis that whether k the treatment / class means are equal which can be formally stated as

$$\mu_1 = \mu_2 = \mu_3 = \cdots = \mu_k$$

Suppose, for example, the researcher wants to test whether the average body and texture score assigned by a panel of judges to different makes of kulfi differs significantly or not. Here the mathematical model under consideration is

$$X_{ij} = \mu + \tau_i + \epsilon_{ij}$$

where $X_{ij}$ is the $j$th observation belonging to $i$th class, $\mu$ is general mean, $\tau_i$ is the effect of $i$th class and $\epsilon_{ij}$ is the random error component which is normally independently distributed with zero mean and constant variance $\sigma^2$. For detailed statistical analysis one may consult any standard textbook of statistics.

4.2 Two way Analysis of Variance (with one observation per cell)

The basic objective in this method is comparison among all treatments within a small block of experimental material, thus reducing the effect of error variation. The mathematical model for two way analysis of variance is given as under:
$X_{ij} = \mu + t_i + b_j + e_{ij}$ where $\mu$ is general mean, $t_i$ is effect due to $i$th treatment ($i = 1, 2, \ldots, t$), $b_j$ is the effect due to $j$th block ($j = 1, 2, \ldots, b$) and $e_{ij}$ is random error component assumed to be NID ($0, \sigma^2_e$). The model assumes additivity of block and treatment effects i.e., there is no joint effect of the $t_i$ and $b_j$. For example, suppose that a processor of dairy products is interested in comparing four storage procedures. The variable of interest is the index of the bacterial count after 72 hr of storage. Since the milk received is variable with respect to the bacterial count, the researcher wishes to experiment with several lots / batches of milk, say, five batches which constitute his replicates of experimental data. His objective is to find the significant differences among storage treatments and batches with respect to bacteria count present in the milk which can be done by using two-way analysis of variance.

5. FACTORIAL EXPERIMENTS

Experiments where the effects of more than one factor say fat / TS levels, sugar levels etc. on the dairy product prepared are considered together are called factorial experiments, while experiments with one factor say only fat/TS or sugar, may be called simple experiments. For example, the quality of ice cream or kulfi depends on the particular fat/TS level as well as also on the particular sugar level used which gives the best quality of ice-cream or kulfi. The only way to know the effect of different fat/TS levels in the presence of different sugar levels (or vice-versa) is to have all possible combinations of the fat/TS and sugar levels in the same experiment with two factors and select a combination of two factors which gives the best quality ice-cream or kulfi. Similarly, these factorial experiments can be extended to three or more factors each at different levels but then the analysis becomes more complicated.

5.1 Two-Factor Experiments

Sometimes a researcher may be interested in examining the effect of two classes of treatments, or 'factors'. For example, in the milk storage experiment mentioned in the previous section, he may be interested in studying both the effect of different types of containers and the effect of different storage temperatures. Here he is interested not only in the individual effect of each of these factors but also in their joint effect known as interaction effect. That is, certain temperatures may work better in conjunction with particular containers than with others.

To take another example, the researcher may be interested in examining the effect of various malt levels and sugar levels and their interaction on the quality of sterilized malted milk evaluated for overall acceptability by a panel of judges. For this design, we establish the following mathematical model:

$X_{ijk} = \mu + M_{ij} + S_j + (MS)_{ij} + e_{ijk}$

where $\mu$ is general mean; $M_{ij}$ = Effect of $i$th malt level

$S_j$ = Effect of $j$th sugar level

$(MS)_{ij}$ = Effect of interaction between malt level and sugar levels in $ij$th cell, and $e_{ijk}$ is the random error component assumed to be independently normally distributed with zero mean and constant variance.
Statistical methods

We assume that $\sum M_i = \sum S_j = \sum (MS)_{ij} = 0$. Here the total sum of squares will be split into sum of squares due to malt level, sugar level and their interaction and the error sum of squares. For detailed statistical methodology one can refer to any standard text book of statistics given at the end.

If, in the above experiment, it is found that the interaction effect is significant one can find out best possible combination of malt and sugar level which gives the best quality of sterilized malted milk based on mean overall acceptability scores for various combinations of malt and sugar levels.

5.2 Three Factor Experiments

It is not necessary that the researcher should limit his investigation to two factors. For example, in a study of Process Optimization for Acidified Milk Beverage, the researcher prepared beverage using four sugar levels, three pH levels and three types of acids. The beverage so prepared was subjected to sensory evaluation by a panel of judges for its body and texture and flavour. The objective of the experiment was to find whether the quality of beverage is affected by different sugar levels, pH levels, types of acids and their interaction. This is three factor experiment. The details of the experiment are given as under:

Factor A: Sugar Levels: 14%, 16%, 18%, 20%
Factor B: pH Levels : 3.75, 4.00, 4.25
Factor C: Types of Acids: Phosphoric Acid, citric acid, lactic acid
Number of Replicates : Three

On the basis of significant interaction effect, the researcher selected pH-sugar combination and type of acid which gave best quality of beverage based on flavour and body and texture score. The mathematical model used can be given as under:

$$X_{ijk} = \mu + S_i + P_j + A_k + (SP)_{ij} + (SA)_{ik} + (PA)_{jk} + (SPA)_{ijk} + e_{ijk}$$

where $\mu$ is general mean, $S_i$ is effect of $i$th sugar level, $P_j$ is effect of $j$th pH level and $A_k$ is effect of $k$th type of acid and $(SP)_{ij}, (SA)_{ik}$ and $(PA)_{jk}$ are two factor interaction effects and $(SPA)_{ijk}$ is three factor interaction effect and $e_{ijk}$ is random error component assumed to be independently normally distributed with zero mean and constant variance $\sigma^2$.

Factorial Experiments, as the number of levels of each factor increases, the number of experiments required for factorial design becomes unreasonably large. For this reason fraction replication of factorial experiments are generally recommended for these designs with four or more levels. Even with the increase in the number of factors, the factorial design becomes more complicated and involves large number of interaction effects and interpretation of results becomes quite cumbersome. In such cases, the higher order interactions which are irrelevant and non-significant may be ignored and their sum of squares and degrees of freedom may be pooled with error component.

6. NON-PARAMETRIC METHODS

Sometimes we come across cases in which we do not know what kind of population we are sampling i.e., we do not know the shape of the population distribution. The tests have
been designed assuming that our samples either were large or come from normally distributed population. But populations are not always normal. In such cases, distribution-free tests or more commonly known as Non-parametric tests are used which do not make restrictive assumptions about the shape of the population distributions. In sensory evaluation where scores are assigned by judges we do not know the shape of the population distribution. A large number of tests are available but a reference to important tests is given as under:

Although I have tried to cover a number of statistical procedures to analyse sensory evaluation data yet they are not complete in all respects. However, depending upon the objective of investigation and looking into the quality of data, statistical procedures can be used for meaningful analysis of data.

SUGGESTED READINGS

III. JUDGING OF MILK & MILK PRODUCTS
1. INTRODUCTION

The sensory evaluation of milk is of utmost importance. Packaged and retail sale of fresh milk comprises a major share of Indian dairy industry (both in the organised and unorganised sectors). Since fluid milk is consumed by most everyone everyday it is being assessed daily for its quality. If the flavour of milk is not appealing or appetising less of it will be consumed.

The sensory characteristics of any dairy product is dependent on the quality attributes of milk ingredients) used. FINISHED MILK PRODUCTS CAN NOT BE BETTER THAN THE INGREDIENTS FROM WHICH THEY ARE MADE. If the raw milk supply is properly assessed for its sensory quality all off-flavour defects due to raw milk could be minimised if not eliminated.

Among dairy product judges the scoring or differentiation of milk into different quality classes demands keener, more fully developed senses of smell and taste than in the sensory evaluation of other dairy products. Many of the off-flavours present in fluid milk are more delicate, less volatile or more elusive than those present in other milk products.

Milk, may be raw or pasteurised, skim or whole, toned or double toned, standardized or full-fat, cow or buffalo. For the purpose of present discussion, milk would mean PASTEURIZED, STANDARDIZED (MIXED) MILK unless otherwise specified. Pasteurization is effected by heating the milk to 72°C for 15 sec or 63°C for 30 min in HTST or LTLT respectively.

PASTEURIZED milk commonly possesses some degree of a heated or cooked flavour especially immediately after processing, but the intensity of cooked flavour diminishes during storage. The flavour of milk is affected by:

a. heating-up and cooling time
b. temperature difference between the product and heating medium
c. velocity of the product in a continuous system
d. occurrence of product 'burn on', and
e. direct Vs indirect heating methods.

The flavour of pasteurized unhomogenized milk undergoes flavour changes during storage as below:

HEATED---> NORMAL---> FLAT---> METALLIC---> OXIDISED
The extent of flavour deterioration depends on the storage time, season of the year, type of roughage fed to the cow and buffaloes and relative levels of cupric or ferric ions.

2. MILK SCORE CARD

The original score card (100 point scale) developed by the ADSA has been extensively modified and is presented on the next page. Bacterial counts, milk temperature and sedimentation test are important data to be provided by the lab. Evaluation of the container/closure is also a valid quality criterion that should be evaluated when required. Flavour on the new score card is evaluated on a 10-point scale. 100 point score card can still be used provided the milk has a bacterial content of 20,000/ml and a maximum temperature of 7.2°C. Familiarity with the score card and use of score card guide is important for milk product judging.

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<th>SCORE CARD FOR MILK</th>
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</tr>
</tbody>
</table>
Sensory evaluation of milk

Table 1. Suggested scoring guide for flavour for milk

<table>
<thead>
<tr>
<th></th>
<th>Intensity of flavour</th>
<th>defect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slight</td>
<td>Moderate</td>
</tr>
<tr>
<td>Astringent</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Barny</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Bitter</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Cooked</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Coco</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Feed</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Fermented/fruity</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Flat</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Foreign</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Garlic/onion</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>High acid</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Lacks freshness</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Malty</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Metallic</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Oxidised</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Light induced</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Metal induced</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Rancid</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Salty</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

3. SOME MILK SCORING TECHNIQUES

3.1 Preparation of samples for evaluation

This depends on the purpose or objectives of evaluation, number of participants and the quality criteria to be assessed. If several persons are to judge the milk samples for flavour, container and closure, sediment and other criteria then several containers of each individual lot of milk must be provided. The sediment test/bacterial count of each sample should be provided.

3.2 Order of examination and scoring

3.2.1 Sediment test

It should be performed first. The kind, amount and size of sediment particles should be carefully observed and scored against a chart or mental image.
3.2.2 Closure

Closure should be carefully observed. Now a days bottles or cartons (not used in India) are not the usual packaging material. The milk is being packaged polyethylene sachets. Hence the evaluator must see that the packaging properly sealed to prevent leakage/pilferage.

3.2.3 Container

Container as stated above, since plastic bags are now in vogue, these should be examined for extent of fullness, cleanliness and freedom from cuts/nicks/pinholes from leakage.

3.2.4 Flavour

The milk should be properly tempered between 13 to 18 °C preferably 15.5°C. Milk samples should be poured into clean, odourless glasses or paper/plastic cups. 10 to 15 ml milk should be poured and a sip taken, rolled around the mouth and flavour sensation noted and then expectorated. Sometimes, any aftertaste may be enhanced by drawing a breath of fresh air very slowly through the mouth and then exhaling through the nose slowly. A full WHIFF of air should be taken soon after the sample is placed in the container for any off-odour that may be present.

3.3 Evaluation temperature

Pasteurized milk should at 7.2°C but lower than 4.4 °C is preferred. A 2-point scale may be used. If the temperature is above 7.2°C the sample may be scored ZERO. Samples at 4.4 °C or below should be scored a perfect or 2 score.

3.4 Evaluation of sediment

Consumers want that the milk should be free from foreign matter. A 3-point scale may be employed. Presence of any sediment is serious and should receive a ZERO score. One possible scoring system could be:

<table>
<thead>
<tr>
<th>Sediment Level</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>no sediment</td>
<td>3</td>
</tr>
<tr>
<td>&lt; 0.02mg/disc</td>
<td>2</td>
</tr>
<tr>
<td>0.025mg/disc</td>
<td>1</td>
</tr>
<tr>
<td>&gt; 0.025mg/disc</td>
<td>0</td>
</tr>
</tbody>
</table>

3.5 Evaluation of milk flavour

Typically the flavour of milk should be PLEASANTLY SWEET AND POSSESS NEITHER A FORETASTE NOR AN AFTERTASTE other than that imparted by the natural richness due to milk fat and milk solids.

When milk clearly exhibits the so-called TASTE there is usually something WRONG with the flavour of the milk sample. Thus milk is considered to have a defect if it has an odour, fore- or after-taste and does not leave the mouth in clean, sweet, pleasant condition,
following tasting. The scoring guide lists most frequently observed off-flavours. The defects should be described while scoring.

4. UNDESIRABLE FLAVOURS

4.1 Acid
Sour detected by taste and smell—due to microbial conversion of lactose to lactic acid, which imparts a tingling effect.

4.2 Astringent
Not common in milk.

4.3 Barny
Transmitted off-flavour due to poor ventilation, foul smelling environment. Perceived by sniffing and tasting. Characteristic aftertaste.

4.4 Bitter
Associated with other defects— astringency, rancidity due to weeds and microbial (psychrotrophs) growth.

4.5 Cooked
Heat-induced. Appears when milk is heated to 76°C or more. There are 4 types of heat-induced flavours: COOKED/SULPHURIOUS; HEATED OR RICH; CARAMELISED and SCORCHED Heated and cooked flavours are easily identified, reaction time is quick, sensation remains after expectoration. Cooked flavour may also be noted through smell.

4.6 Cowy (acetone)
Distinct, persistent unpleasant, medicinal chemical aftertaste with acetone bodies in milk i.e., ketosis in cows.

4.7 Feed
Imparts aromatic taints to milk when fed 1/2 - 3 hours prior to milking. The off-flavour is aromatic sometimes pleasant (e.g. alfalfa - alfalfa), detected by smell. Varies with feed. To prevent such feeds should not be fed 3 hours prior to milking.

4.8 Fermented/Fruity
Due to microbes, resembles vinegar, pineapple, apple. Found in old pasteurized milk, due to growth of Pseudomonas sp. (P. fragilis).

4.9 Flat
Flat taste/mouthfeel—lack of richness.

4.10 Foreign
Smelled or tasted, due to chemicals/detergents, disinfectants, sanitisers, exposure to fumes of petrol, diesel, kerosene, insecticides, ointments, medication to cows etc.

4.11 Garlic/Onion (weedy)
Pungent odour and persistent aftertaste.
4.12 Lacks freshness (stale)
Taste reaction indicates loss of fine pleasing taste, slightly chalky. May be 'forerunner' of either oxidised or rancid off-flavour or off-flavour caused by psychrotrophs.

4.13 Malty
Flavour definite or pronounced, suggestive of malt caused by the growth of S. lactis var. maltigenes at >18.2°C for 2-3 hours can be smelled or tasted. Bacterial population in millions, followed by acid/sour taste.

4.14 Metal-induced oxidised off-flavour
Due to lipid oxidation-metal catalysed. Metallic, oily, cardboardy, cappy, stale, tallowy, painty and fishy are used to describe this off-flavour. The off-flavour is quickly perceived in the mouth and has a relatively short adaptation time.

4.15 Light-induced oxidized off-flavour
Described as burnt, burnt protein, burnt feathers, cabbage, medicinal or chemical-like, light-activated or sunlight flavour or sunshine flavour, light catalysed lipid oxidation as well as protein degradation both are involved. It requires riboflavin which is naturally present in milk. Homogenised milk is more susceptible but is resistant to oxidised off-flavour (due to lipid oxidation) the opposite is true for non-homogenized milk.

4.16 Rancid
Extremely unpleasant, due to volatile fatty acids formed through enzymatic hydrolysis of fat. Soapy, bitter and unclean aftertaste. Flavour is nauseating and revolting.

4.17 Salty
Perceived quickly in the mouth

4.18 Unclean
Due to growth/activity of psychrotrophs at >7.2°C.
SENSORY ATTRIBUTES OF TABLE BUTTER AND THEIR ASSESSMENT

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Sr. Scientist
Dairy Technology Division
NDRI, Karnal- 132 001

1. INTRODUCTION

Butter has a very mild and delicate flavour which however is an important contributor to the product’s acceptability. Texture of butter is very typical and its defects highly characteristic. Appearance is relatively less important but cannot be ignored.

2. FLAVOUR

A high quality butter is expected to possess mild, sweet, clean and pleasant flavour and a delicate aroma—which is due to the composite effect of flavour of butterfat and the flavour of the serum. To manufacture butter with most desired flavour the raw material used must definitely be free from objectionable flavour defects. This is also true of cultured cream butter, which should have a distinct, starter flavour aroma (diacetyl as the principal component)

2.1 Flavour defects in butter

For evaluating butter flavour, the judge should recall the aroma noticed at the time the trialful of butter was obtained. The judge should then remove about 1 inch of the end section of the butter plug with a knife, spoon or spatula and place this in mouth. Butter should then be chewed and brought into a liquid state as soon as possible. The sample should be manipulated with the tongue and jaws until butter sample reaches body temperature. The judge should then notice the first hint of a taste or smell. The melted sample then may be drawn to the back of the mouth to notice the taste and smell. To prevent sensory adaptation, the sample of butter should not be kept in mouth for too long. All the sensory observations should be recorded on a score card, by assigning each item an appropriate numeral value. Some of the common flavour defects associated with butter are discussed below.

2.1.1 Acid or sour: An acid off-flavour in butter is characterized by a sharp sour taste on the tip of the tongue.

2.1.2 Aged: Butter lacks freshness, can easily be detected by smelling the sample or by noticing a moderately persistent aftertaste. The defect is caused by either holding butter too long at relatively low temperature or for short periods at relatively high temperatures.

2.1.3 Bitter: Bitterness resembles the taste sensation similar to 'quinine'. It persists as a distinct, lingering aftertaste, even after the sample has been expelled from the mouth. To
detect it the sample should be melted in the mouth and rolled to the back centre of the
tongue where taste buds sensitive to bitterness are located.

2.1.4 Cheesy: Flavour resembling that of cheddar cheese. From the instant of placing the
sample in the mouth, through manipulation of the sample and subsequent expectoration, to
the last lingering aftertaste, this flavour defect is readily noticeable.

2.1.5 Briny / High Salt: A distinct 'Salty' taste that is beyond a range of ordinary
acceptability.

2.1.6 Coarse: Butter that lacks the pleasant flavour sensation or the balanced taste and
aroma that is anticipated in high quality product is referred to as 'coarse'. In fact, a coarse
flavoured butter has reasonably good sensory properties but just seems to fall short of the
top or best quality product.

2.1.7 Cooked: Cooked flavour is generally associated with high quality (best grade) butter.
This flavour is readily recognized when the core sample (within the trier) is passed under the
nose or when a portion of the sample is first placed into the mouth.

2.1.8 Feed: Presence of different feed (hay, silage etc.) flavours. It can easily be detected in
the aroma and verified on the palate when the butter is melted.

2.1.9 Fishy: Butter may have a flavour and aroma similar to codfish, cod-liver oil or fish
meal. This is one of the most serious, most pronounced and objectionable flavour defects of
butter. It is an off flavour which is persistent and the mouth distinctly fails to clean up.

2.1.10 Flat: Butter that simply lacks a characteristic full, pleasing 'buttery' flavour is
criticized as being 'flat'. The absence of typical butter flavour is noted when the butter is first
placed into the mouth.

2.1.11 Foreign: As described for milk and cream.

2.1.12 Garlic or onion: These Off-flavours, occasionally found in butter, are easily detected
from characteristic smell.

2.1.13 Malty: As described for milk and cream.

2.1.14 Musty: The 'musty' Off-flavour in butter resembles the odour of a poorly ventilated
musty smelling space or room. It is also attributed to the growth of a specific spoilage
micro-organism (Pseudomonas taetrolens).

2.1.15 Oxidized: Oxidized flavour is frequently noticed as a surface taint in butter.

2.1.16 Rancid: Rancidity resembles the pungent, rasping taste and odour of darkened,
decayed nut-meats.

2.1.17 Tallowy: This off-flavour is caused by an extensive degree of oxidation of the
unsaturated fatty acids in milk fat. It resembles tallow.
2.1.18 Yeasty: A 'yeasty' off-flavour is detected in the early stages of development by the typical fruity, vinegary, and slightly fragrant aroma, which is apparent when the sample is first taken into the mouth.

3. BODY AND TEXTURE OF BUTTER

The term Body & Texture is used to describe the physical property that is examined on the basis of touch, appearance and mouthfeel. Though the exact meaning of this term is not very clearly defined, in general body refers to the make up of the mass while texture to the arrangement of the particles that make up the mass. Body & Texture are in fact so closely related that they are not considered separately in judging physical properties of a product.

3.1 Desirable characteristics

Body and texture of butter is affected markedly by temperature. It is necessary, therefore, to define the temperature at which these properties are evaluated. The tactile properties of butter should be evaluated at a product temp. between 77 and 13°C. Within this temperature range the body of the butter should be firm, waxy and consist of such closely knit granules that it appears as a uniform mass. Water and air, in proper amounts, should be uniformly distributed and closely bound. The ideal butter should cut easily and evenly when sliced and be readily spreadable.

Some body and textural characteristics may be assessed by carefully observing the plug and backside of the butter trier. A good butter should not adhere to the back of the trier nor should there be any visible water droplets. The plug should be well rounded, have smooth, waxy breaks or openings. Some of the major body & textural attributes are discussed below:

3.2. Body and texture defects in butter

3.2.1 Crumbly or brittle: Butter particles lack cohesiveness and do not hold together. Some of the butter usually adhere to the trier and reflects rough appearance. Butter cannot be cut into neat portions for table use- it appears dry and readily falls apart.

3.2.2 Greasy: Greasy butter consistency may be noted by the evidence of extreme smoothness and immediate melting when a sample of such butter is placed into mouth. The defect may be suggested by the extreme ease with which a trierful of sample may be removed from the product.

3.2.3 Gummy: Butter does not melt readily when tasted, but adheres to the root of the mouth. This defect is more prevalent in cottonseed fed area. The defect is due to higher percentage of high melting point glycerides. This defect markedly interferes the spreadability of butter.

3.2.4 Leaky: Butter shows beads or droplets of moisture on the plug and/or the back of the butter trier.
3.2.5 *Mealy or Grainy*: Butter shows ragged surface on the trier plug and does not spread or cut well. When taken into the mouth and compressed between the tongue and palate, a distinct 'grainy' sensation is perceived.

3.2.6 *Sticky*: Butter sticks to the trier and appears to be quite dry. Usually it is difficult to secure a uniform, smooth-surfaced plug from such butter, it appears 'ragged or rough'. This is particularly true when the trier is cold. This butter is difficult to slice or spread.

3.2.7 *Weak or spongy*: The defect is typically indicated by a quick meltdown and excessive softness of butter.

4. **COLOUR AND APPEARANCE**

The colour of butter may vary from light creamy white to dark creamy yellow or orange. While moderately high colour may be preferred in one region, a lighter colour may be considered more desirable in another. A uniform light straw colour may be the most acceptable to the consumer. The primary feature to observe in sensory evaluation of butter for colour is uniformity of colour.

4.1 Defects in colour & appearance

Faulty workmanship, particularly over and under working of butter during manufacture is responsible for most colour & appearance defects. The size, number and distribution of moisture and air droplets, markedly influence the colour of butter.

4.1.1 *Mottled*: Butter with spots of lighter and deeper shades of yellow.

4.1.2 *Wavy or streaky*: Butter with distinct waves of different shades of yellow, with colour in each wave more or less uniform.

4.1.3 *Speckled*: Butter with coloured specks of foreign matter scattered through it.

4.1.4 *Primrose or high colour surface*: This is deepening of colour of the exposed surface of butter.

4.1.5 *Mould discoloration*: Moulds growing on the surface of butter may produce wide range of colours.

5. **SALT**

Salt renders the flavour of butter to be more attractive. Preference for the amount of salt in butter may differ with individuals. Some consumers prefer a highly salted butter (> 2%), some desire a lightly salted (< 1.5%) while others prefer exclusively unsalted butter. Salt is not generally criticized in butter grading regardless of whether the butter is high or low in salt provided salt is completely dissolved (is not gritty) and it is not too 'sharp'.

In order to get a perfect score for salt, salt in the interior of the butter must be completely dissolved. Undissolved salt on the surface of an exposed sample of butter does not necessarily indicate presence of undissolved salt in butter (gritty butter). The presence of
Sensory attributes of butter

'grittiness' can most easily be detected by placing some butter between the molars and pressing together gently.

6. PACKAGE

Package serves to adequately protect the product. Butter package, whether for retail or wholesale, should be neat, clean and tidy in appearance. It should have good finish and should appear fresh and unsoiled.

7. REQUIREMENTS AND PROCEDURE FOR GRADING OF BUTTER

7.1 Tempering of butter

The temperature of butter at the time of grading is quite important for determining the true body & texture characteristic and to readily detect the delicate aroma of bulls. Temperature of sample should be maintained between 7-13°C. Butter should be placed in the tempering room well in advance to allow tempering to about 10°C. (the required time will depend on relative size & temperature of butter sample).

7.2 Use of butter trier

A butter trier should be used for drawing samples from butter block or package. Facilities for cleaning the trier (soft tissue or absorbent paper) and disposal of waste butter should also be provided. Use of hot water for cleaning the trier be avoided.

7.3 Use of butter score-card

Butter score card (Fig. 1) and scoring guides (Tables 1, 2 & 3) are useful instruments for the butter grader. It assist him in the quality assurance endeavour of the organization.

Table 1. Maximum scores for butter attributes as per the ADSA score-card

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Maximum score</th>
<th>Nominal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavour</td>
<td>10</td>
<td>1 - 10</td>
</tr>
<tr>
<td>Body &amp; texture</td>
<td>5</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Colour &amp; appearance</td>
<td>5</td>
<td>1 - 5</td>
</tr>
<tr>
<td>Salt</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Package</td>
<td>2</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 2. A suggested scoring guide for the flavour of butter

<table>
<thead>
<tr>
<th>Flavour Defect</th>
<th>Slight</th>
<th>Moderate</th>
<th>Definite</th>
<th>Strong</th>
<th>Pronounced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>Bitter</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>0-3</td>
</tr>
<tr>
<td>Cheesy</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Coarse</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cooked</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Scorched</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>0-2</td>
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<tr>
<td>Feed</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>0-5</td>
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<tr>
<td>Fishy</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Fhr</td>
<td>9</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>-</td>
</tr>
<tr>
<td>Foreign</td>
<td>0-3</td>
<td>0-2</td>
<td>0-1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Garlicicton</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>High salt (briny)</td>
<td>8</td>
<td>7</td>
<td>6</td>
<td>5</td>
<td>0-4</td>
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<td>Malty</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Musty</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>0-1</td>
</tr>
<tr>
<td>Neutralizer</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Old cream</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>0-2</td>
</tr>
<tr>
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Table 3. A suggested scoring guide for body and texture and colour and appearance in butter

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</table>
Sensory attributes of butter

7.4 Sequence of observations

a. Observe the cleanliness and neatness of the package.
b. Remove the cover/packaging material and observe the sample for its evenness and/or
   squareness of the wrapping material.
c. Insert the butter trier diagonally near the centre of the package and draw a sample plug
   of butter.
d. Immediately after withdrawing the plug pass the trier slowly under the nose, through the
   nose very slowly and notice the odour or aroma present.
e. Examine the colour for uniformity through.
f. Examine the body & texture by pressing the ball of the thumb against the sides of the
   plug until it shows a break (observe the presence or absence of free moisture and their
   relative clarity and also the nature of the break).
g. Break off approximately 0.5 to 1 inch piece from the end of the butter plug and place it
   into the mouth. Chew it until it melts and then roll the melted sample around the mouth
   till it reaches body temperature. Meanwhile examine the presence of 'grit' (undissolved
   salt) and the manner in which butter, melts. Also notice the various sensations of taste
   and smell.
h. Expectorate the sample and carefully observe for the occurrence of possible after taste
   and persistence of any off-flavour.
i. After judging each sample rinse the mouth frequently with 1.0% warm saline water.
j. With the help of butter scoring guide record the assigned sensory score of the product.

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1. INTRODUCTION

Soft unripened cheeses are commonly known as "Fresh Cheese" and are made by coagulating either whole milk, partly skimmed milk, skim milk or cream, eliminating a large part of the liquid portion (whey) and retaining the coagulated milk solids. The amount of water retained in the curd greatly influences the relative softness of unripened cheese made from milk having constant casein-to-fat ratio. Softness of cheese also depends on the extent of protein hydrolysis, salt content and the amount of milk fat in cheese. Soft unripened cheese derive their flavour mainly from the culture and the cream dressing. Cottage cheese, Cream cheese, Mozzarella cheese, Ricotta cheese, paneer etc. are some of the common varieties of fresh cheese. They differ from each other in their method of manufacture with respect to type of milk, treatment given to milk, type of culture, amount of culture, method of coagulation, cutting of curd, cooking of curd, pressing of curd etc.

Consequently, they differ in sensory as well as chemical attributes. The desirable sensory attributes of fresh cheeses, defects and their probable causes and remedies with special reference to cottage cheese are described in this lecture note.

2. COTTAGE CHEESE

Cottage cheese is a fresh, soft, unripened cheese made from sweet, pasteurised skim milk by lactic culture with or without the addition of rennet. The curd is cut and cooked to facilitate whey expulsion and development of proper curd consistency. When the curd has attained the desired consistency, whey is drained off, curd is washed and salted. Subsequently, the curd is dressed with cream in the case of creamed cottage cheese which contains 4% fat. Cottage cheese contains 80% moisture.

2.1 Desired sensory attributes

2.1.1 Appearance and colour

The curd particles of cottage cheese should be distinctly separate and uniform in size and shape. The cheese should possess moderately glossy sheen and creamy white colour. The cream dressing should be reasonably viscous and foam free, and bulk of it should adhere to the curd particles. The excess dressing should form only a uniform and smooth coating on the curd particles. Free cream, free whey, lack of uniformity and the presence of lumps or curd dust are considered as common appearance defects in cottage cheese caused mostly by faulty method of manufacture viz., excessive cooking, insufficient washing, cutting
of curd at too high or too low pH, rapid cooking, uneven cutting or cutting with a faulty knife or aggressive stirring, low TS milk, excessive heat treatment of skim milk, use of excessive coagulator, severe stirring or rough handling of curd during cooking etc. Appropriate corrective measures during manufacture of cottage cheese eliminate these defects.

2. 1. 2 Body and texture of cottage cheese

Ideally, creamed cottage cheese should have a tender body, and smooth and meat like texture. Curd particles should maintain their shape and individual identity but should not be too firm, rubbery or too soft. Smooth, meaty and tender curd particles exhibit good capillary desired for complete absorption of cream dressing common body & texture defects are listed below:

2.1.2.1 Too firm body: Firm or rubbery bodied curd particles of cottage cheese resist crushing between tongue and roof of the mouth. This defect occurs due to over use of rennet or other milk coagulator, cooking of curd at too high temperature and for too long, or cutting of curd at a pH more than 4.7

2.1.2.2 Mealy / Grainy / Gritty: Presence of this defect gives a corn meal like sensation in the mouth when masticated curd is pressed by the tongue against the roof. Also, a dry rough and serrated curd mass is observed when the washed curd particles of creamed cottage cheese are kneaded and smeared between the forefinger and thumb. The defect may be caused by overdeveloping the acid during curd formation; retention of too low moisture, non-uniform cutting of coagulum, uneven heating, too rapid cooking, inadequate stirring, and curd particles coming in contact milk extremely hot surfaces during cooking.

2.1.2.3 Gelatinous: Gelatinous cheese has a jelly-like and sticky character. Often this defect is associated with a bitter flavour and translucent appearance. This defect is caused by psychrotrophic bacteria.

2.1.2.4 Weak / soft / mushy: This defect is characteristic of a high moisture, low-solid cottage cheese. It is caused by faulty manufacturing methods which favour retention of whey in the curd. On storage such cheese may become pasty and bitter.

2.1.2.5 Overstabilized dressing: When this defect occurs the creamed cottage cheese appears dry and some individual curd particles are surrounded by a thick, pasty, coating. This usually happens due to the use of excessive amount of non-fat dry milk, stabilizers and/or emulsifiers.

2.1.3 Flavour

Cottage cheese should have a fresh, clean, pleasant delicate (balanced culture) flavour that cleans up well immediately after the sample has been eliminated from the mouth. This flavour is made up of characteristic curd flavour and its acidity, volatile products by lactic acid organisms. Addition of cream and salt enhance the flavour of creamed cottage cheese. The probable Cottage cheese being highly perishable product is prove to the development of specific flavour defects as discussed below:
2.1.3.1 Acid/high acid/sour: Acid taste is clean and sharp while sour taste is pronounced and may be associated with other bacterial defects like fruity, fermented etc. Excessive acid development and/or insufficient washings of the curd cause this defect. Such product is sometimes also criticised for flavour defect like "whey taint".

2.1.3.2 Bitter : Bitter flavour is characterised by its relatively slow reaction time; taste at or near the back of the tongue only; freedom from astringency; and persistence after expectorating the sample. The defect is most frequently encountered in old cottage cheese or in the sample stored at a temperature favourable for the growth of Pseudomonas organisms.

2.1.3.3 Flat : Absence of characteristic flavour or aroma is termed as flat flavour. A dry, unsalted and washed rennet curd yields a distinctly flat taste during the intermediary stages of oxidized flavour development.

2.1.3.4 Lacks freshness : The flavour of cottage cheese is its best immediately after manufacture. Cottage cheese progressively deteriorates in flavour during storage. Often this defect is referred as storage flavour because the aroma of cheese is similar to that of the refrigerator in which it was stored.

2.1.3.5 Fruity / Fermented : This defect is characterised by the presence of a pleasant aromatic flavour suggestive of pine apple, apple, banana or strawberry and distinctive lingering aftertaste. The cottage cheese stored at elevated or favourable temperatures for the psychrotrophic bacteria may develop this defect.

2.1.3.6 Yeasty : Yeasty and vinegar like flavours have a peculiar aromatic quality in addition to high acidity. Yeasts and various other contaminants including psychrotrophic bacteria are generally responsible for causing this flavour defect.

Other flavour defects in cottage cheese include malty, musty, oxidised, rancid, salty and unclean flavours.

3. CREAM CHEESE

Cream cheese is a soft, unripened cheese made by coagulating cream (12-30% milk fat) either by lactic acid bacteria aided by milk coagulating enzymes or by direct acidification followed by removal of whey by centrifugation or pressing the curd in cloth bags. The fat content in the final product varies from 3 to 40%. Neufchatel cheese is a similar product made from whole milk of high fat contents. It contains about 20-25% fat.

3. 1 Desirable sensory attributes

3.1.1 Flavour

Cream cheese should have a full rich, clean and mild acidic flavour. Neufchatel type cheese may have a moderate acid taste. More common flavour defects in various types of cream cheese may be flat, sour or too high acid, metallic, yeasty and unclean after taste.
3.1.2 Body and texture

Soft yet sufficiently firm body to retain its shape is the characteristic of cream cheese. The texture should be somewhat buttery and silky smooth. It should possess both spreading as well as slicing characteristics. Cream cheese prepared from cream containing 16% fat exhibits most desirable body and texture properties. In such cheeses the moisture and fat content may vary in the ranges of 50-54% and 37-42%, respectively. Cream containing less fat yields a cream cheese which is criticised as having grainy texture and crumbly body. Increased fat content of cream (20%) results in excessive smoothness and stickiness. Other body and texture defects of cream cheese include coarse, grainy, too firm and too soft.

4. MOZZARELLA CHEESE

It is a soft unripened variety of cheese of Italian origin. It is produced from whole or partly skimmed milk to which small amounts of starter or organic acids are added, followed by rennet extract. The curd is cut, allowed to firm up in the warm whey with occasional stirring and the whey is drained off. When the curd has developed the desired plasticity and fibrous texture and the whey acidity 0.65 - 0.70% L.A, it is milled. The curd pieces are immersed in hot water kneaded, stretched and moulded. Salting of cheese is done by dipping the cheese in brine solution for few days. The cheese can be consumed after the brine treatment is complete.

4.1 Desirable sensory attributes

4.1.1 Colour and appearance

Mozzarella cheese should have a uniform white to light cream colour. Faulty manufacturing method and microbial contamination may sometimes cause colour defects in the product. Use of too high salt may cause discoloration. Development of browning may be caused by using starter culture containing only Thermophilus. Contamination with Pseudomonas spp. causes development of superficial reddish marks.

4.1.2 Body and Texture

Mozzarella cheese should have a soft, elastic, waxy and moist body with typical structure of pulled curd cheese. It should have a fibrous texture with no gas holes. It should possess a good slicing as well as melting properties. Use of too high salt or growth of Lactobacillus casei may cause poor melting quality. Undesirable microbial contamination may cause development of defects, like pigmentation, hole formation and other textural defects. Rapid evaporation of moisture from the surface leads to the development of granular texture.

4.1.3 Flavour

Bland, pleasant but mildly acidic with slightly salty taste is the characteristic of mozzarella cheese. Buffalo milk cheese is a more piquant and aromatic than cow milk cheese. Microbial contamination, particularly with Pseudomonas species may lead to the
Sensory evaluation of fresh cheese

development of flavour defects like putrid smell, bitter flavour etc. Other flavour defects may be of absorbed or chemical nature as in the case of cottage cheese.

5. RICOTTA CHEESE

It is yet another variety of soft unripened cheese of Italian origin. In the manufacture of ricotta cheese, mixture of whey and skim milk is acidified to a critical pH with lactic acid, acetic acid or acid whey powder and then heated. The resulting curd is recovered and over filled in perforated tin containers, cooled and allowed to drain free whey. Cheese is now ready for consumption. Ricotta cheese made from whole milk is consumed directly while made from skim milk or whey skim milk mixture is highly suited for pastry manufacture.

Ricotta cheese from whole milk resembles highly creamed, cottage cheese but has a softer and more fragile texture. A mixture of skim milk whey yields a firmer and drier product which lacks its distinctive nutty flavour. In general ricotta cheese is soft, and creamy with a delicate, pleasant and slight caramel flavour.

Ricotta cheese is highly susceptible to spoilage due to microbial contamination leading to flavour defects like sour, fermented, fruity etc. Excessive gas formation may also cause blowing of the lid of the container.

6. PANEER

Paneer is an indigenous milk product made by coagulating heated milk preferably buffalo milk (6% fat) acid solution and/or sour whey. The whey is drained and the curd filled in hoops and pressed. The pressure is removed after 10-15 min and the paneer is cut into pieces and immersed in chilled water for cooling.

6. 1 Desirable sensory characteristics

6.1.1 Colour and appearance

Paneer should have uniform white colour with greenish tinge if made from buffalo milk and light yellow if prepared from cow milk. Paneer may develop colour and appearance defects as listed below:

6.1.1.1 Dull: This defect is recognised by its dead, unattractive appearance and suggest lack of cleanliness in manufacture.

6.1.1.2 Dry surface: Use of milk containing excessive amount of fat gives paneer with dry surface and unattractive appearance.

6.1.1.3 Surface skin: Exposure of paneer while hot to the atmosphere causes rapid evaporation of moisture from the surface resulting into the formation an undesirable yellow skin on the surface.
6.1.1.4 Visible dirt / Foreign Matter: This defect may occur due to improper straining of milk, use of dirty water, dirty, windy surrounding, poor packaging and careless handling of paneer.

6.1.1.5 Mouldy surface: Long storage of product in humid atmosphere coupled with higher moisture content flavours development of moulds on the paneer surface.

6.1.2 Body and texture

The body of paneer should neither be too firm nor too soft. It should retain its shape. The texture of the high grade paneer should be compact, smooth elastic and velvety.

Paneer develops body and texture defects due to faulty manufacturing methods and microbial contamination. Excessive retention of moisture due to low coagulation temperature, delayed straining or incorrect pH of coagulation often gives a paneer with soft body and pasty texture. Low moisture content in paneer caused by higher coagulation temperature, incorrect pH at coagulation, use of low fat milk, yield hard and rubbery bodied paneer. Such paneer may also have a mealy texture. Frozen storage of paneer causes crumbly body and coarse/mealy texture in paneer.

6.1.3 Flavour

Flavour of paneer is a characteristic blend of the flavour of heated milk curd, and acid. The flavour of the high grade paneer should be pleasant, mildly acidic, slight sweet and nutty. Common flavour defects observed in paneer are similar to those as observed in other fresh cheese and can be eliminated by following proper manufacturing method, sanitation, packaging, storage and handling.

SELECTED REFERENCES


1. INTRODUCTION

Cheese is a highly nutritious, pre-digested protein rich milk food popular throughout the world. Cheese is now made in almost the entire world in one form or the other, and is not only considered as one of the main protein sources, but also as a delicacy worthy of the attention of the most exigent gastronome. Besides the well recorded nutritional and therapeutic advantages of cheese as a fermented food, recent researches have established that it has anti-carcinogenic property, prevents tooth decay and is an ideal milk food for lactose intolerants.

2. CHEESE TYPES

There are many different kinds of cheese, depending upon (i) whether made from whole milk or from skim milk, (ii) the method of coagulation of milk, (iii) the amount of moisture retained in the curd, (iv) whether the curd is ripened or unripened, (v) the method of ripening, and (vi) the source of milk, cow, buffalo, sheep or goat. The ripened cheese may be classified as under:

A. Soft cheese (40 to 50% moisture e.g. camembert, etc.)
B. Semi-hard cheese (38 to 40% moisture) e.g. Brick, Blue-veined etc.
C. Hard cheese (30 to 40% moisture) e.g. Cheddar, Swiss etc.
D. Very hard cheese (below 30% moisture) e.g. parmesan etc.

The present discussion pertains to sensory evaluation of hard varieties of cheese viz., Cheddar and Swiss.

3. SENSORY CHARACTERISTICS OF CHEDDAR CHEESE

Cheddar cheese is one of the most common types of cheese produced in the world. It is generally made from flash heated or pasteurised milk to which about 1.0 percent lactic starter culture has been added. The curd formed by the addition of coagulating enzyme is formed by cooking at 39°C. The characteristic body of cheddar cheese is developed by a process of matting the curd known as cheddaring. The curd is pressed, paraffined and cured.

3.1 Kinds of Cheddar cheese

Mostly pasteurised milk cheddar cheese is marketed shortly after manufacture (< 90 days) as a mild cheese or for use in producing processed cheese. The ripening or curing of
Cheddar cheese to develop characteristic cheddar flavour is a slow, complex, bacteriological, chemical and enzymatic process which requires several months. Unripened or "fresh or "green" Cheddar cheese has a flat flavour and relatively tough, curdy or corky body. Cheddar cheese properly cured for at least 3 months or longer has a moderate, slightly nutty, cheddar flavour and is called "young" or "mild" cheese. At 6 to 8 months, more of the distinct, aromatic cheddar flavour should be evident; such cheese is considered as semi or medium aged. Generally, 8-10 months are required to develop the fully aromatic or robust Cheddar cheese flavour desired in an "aged", sha or matured cheese.

3.2. The Cheddar cheese scorecard

The quality of cheese is determined by comparing the properties or characteristics of each cheese with their accepted standards of perfection. For this purpose a score card is used. The American Dairy Science Association has developed a score card for evaluating Cheddar cheese.

3.3. Tempering cheese

Before evaluation, cheese samples should be tempered at 10°C to 15-5°C for a sufficient length of time to ensure uniform temperature throughout the cheese. This usually required 1-2 hrs for small blocks (up to 3 kg) and 3-5 hrs for large ones. Generally a cheese plug taken from a warm cheese appears weak-bodied; by contrast a cold plug may appear brittle or corky.

3.4 Appearance

Typically, the first procedure in grading Cheddar cheese is visual examination of surface finish or packaging material. In general, the appearance should be clean, neat, attractive and symmetrical or the surface might be uneven, non parallel or rounded. The surface should also be free from holes, wrinkles and moulds.

3.4.1 Colour of Cheddar cheese

The evaluator should observe the colour of the cheese and determine whether the appearance is bright and clear or dull and lifeless. The colour of cheese should be uniform (free from mottled or light and dark portions) or whether there are curd scams or faded areas. The cheese plug appears to be translucent. Some of the colour defects associated with cheddar cheese are:

Acid-cut (bleached, faded), a typical colour specks, seamy (uneven wavy), colour too high (unnatural) and white specks.

3.4.2 Body and texture of Cheddar cheese

Cheddar cheese with the most desirable body and texture displays a full, solid, close-knit plug that possesses smoothness, meatiness, waxiness and silkiness, and is entirely free from gas holes or mechanical openings. Such a product lends itself to uniform slicing into intact pieces. The common body defects are: corky (dry, hard, tough), crumbly
Sensory attributes of ripened cheese

(friable), curdy (rubbery), greasy, pasty (smearly, sticky, wet), short (flaky), spongy and weak/soft. The texture defects are mealy, gritty, slits, gassy, fissures and open (mechanical holes).

3.4.3 Flavour of Cheddar cheese

High quality Cheddar cheese should possess the characteristic "cheddar flavour", which is best described as clean, moderately aromatic, nutty like and pleasantly acidic while the same general flavour qualities are desired in fresh, medium-cured and aged cheese, the intensity of the characteristic cheddar flavour will primarily depend upon the extent of curing and actual curing condition. The flavour of high-quality Cheddar cheese has been likened to that of freshly roasted peanuts or hazelnuts by various investigators. Flavour defects in cheddar cheese could be listed as follows:

High acid (sour), bitter, fruity, flat, garlic/onion (weedy), heated, malty, metallic, mouldy (rusty), rancid, unclean, yeasty etc.

4. SWISS CHEESE

Swiss cheese, also known as Emmental, Emmentaler, Schweizer, or Swiss cheese, is a type of hard cheese made from clean, fresh milk. The specific manufacturing conditions are employed which differ widely from those for cheddar cheese. The utilisation of thermophilic lactic bacteria and Propionibacterium shermanii for milk fermentation results in a cheese having flavour, body, texture and appearance characteristics peculiar unto itself. High-quality swiss cheese is characterised by: (i) a cream yellow colour (ii) a shiny surfaced round gas holes, and (iii) a characteristic "sweet hazelnut" flavour.

4.1 Requirements of quality swiss cheese

4.1.1 Flavour

A good quality swiss cheese should have a clean, distinctive, pleasing, sweet hazelnut flavour. Unique to this cheese variety, appropriate 'eye' formation in swiss cheese is considered a good indication of typical swiss cheese flavour. The common flavour defects found in Swiss cheese are as follows: flat, rancid, stinker, unclean, unnatural etc.

4.1.2 Eye development in Swiss cheese

The shape, size, and distribution of the "eyes" in swiss cheese have an aesthetic appeal to consumers in addition to a possible association with typical swiss cheese flavour. Round, symmetrical eyes are preferred in swiss cheese, but a slightly elliptical or oval shape may be accepted without objection. The ideal frequency distribution of eyes in cheese tends to fade towards the edge of the cheese block. The majority of eyes should be about 2 cm in diameter. The defective cheese has too large eyes or numerous small eyes and sometimes absence of eyes. These defects are designated as under: blind, dull, irregular, misshapen, pressler, overset / cabbagy / blow holes etc.
4.1.3 Body and texture of Swiss cheese

The body and texture of high quality Swiss cheese should be firm, closed, moderately flexible when bent and free from such defects as glass, pinholes, sponginess or bloats. Occasion picks (small, irregular or ragged openings) and checks (short cracks) may be tolerated, provided they are within 2 cm of the surface.

4.1.4 Finish and appearance of Swiss cheese

Swiss cheese should be symmetrical, with a smooth, even, clean, dry and closed surface. The ends of cheese pieces should be parallel, neither bloated nor sunken, with surfaces free from cracks, and all edges square. It is most undesirable for cheese edges to exhibit long tabs or a cracked, open edge (frog mouth).

5. CONCLUSION

Sensory characteristics are among the most important attributes of cheese. Cheese analyses for chemical composition, microorganisms, enzymatic activity, physical properties etc. do not measure the true or actual eating quality of the product. Cheese is unique in many ways. No other group of foods possesses such variations in flavour, consistency, appearance or number of categories. Cheese provides a vast panorama of flavour and culinary experience; it truly adds zest to eating. The products unique body and texture as well as appearance characteristics contribute to its special sensory appeal.

SELECTED REFERENCES

1. INTRODUCTION

Critical quality assessment of all classes of concentrated milk challenges both the dairy products judge and the manufacturer of these products. A thorough understanding of the sensory attributes of concentrated milk and their routine examination is imperative, not only to assure improvement of the product, but also for ensuring that the product reaches the consumer in good condition.

2. EVAPORATED MILK

When judging or grading evaporated milk, the judge must keep in mind the desirable qualities and standards for the product. It must be noted that, in addition to meeting the legal chemical requirements for the product high quality evaporated milk must be white to creamy in colour, have a relatively viscous body, be uniformly smooth in texture and possess a mild, pleasant flavour (Bodyfelt et al., 1988).

A complete examination of evaporated milk includes test and observations on colour, container, fat separation, fill of container, film formation (protein break), flavour, gelation, sedimentation, serum separation, viscosity and whipping ability.

Some of the subjective tests, based on organoleptic examination, make use of the hedonic scale or variations of it. For example, the flavour of evaporated milk may be given a hedonic rating on a 9-point scale discussed earlier under "Sensory tests". A narrow band hedonic scale say, a 5-point one, may be used in rating organoleptic quality factors other than flavour.

2.1 Procedure for examination

A routine in examining cans of evaporated milk facilitates judging of the samples. The following steps have been found to be of material aid in going over a lot of samples:

Precaution: Avoid undue agitation when transporting the cans to the laboratory.

a. Examine the cans for appearance, notice the upper end of the can for polish; observe the neatness of the label.

b. Open the can in such a way that both the can and contents may be examined.
c. Notice the colour of the milk which should be uniformly white to cream colour. Intensity of darkening may be noted for its degree e.g. non, slight, distinct and pronounced.

d. Study the body and texture. Smooth, relatively viscous evaporated milk pours like a thin cream without marked splashing. Allow the can to drain well. Look for any deposit which may be present in the bottom of the can. Should the milk lack uniformity try to determine whether the chief factor is fat, protein, salts or foreign material. In case the fat is responsible, the defect will appear at the top of the can as a cream layer or as buttery particles. Defect due to protein will appear as various size curds distributed throughout or as different intensities of gelation.

e. Observe the condition of the container looking for splangling, blackening of the seam and rusting of the container. Splangling appears as clean, bright, dark, overlapping blotches on the surface as though the tin were attacked by acid.

f. Determine the colour reaction in coffee. It should be a rich, golden brown colour. Off flavour may be associated with rust formation in the container.

g. Note the miscibility with coffee. Feathering in hot coffee appears as finely divided, serrated curds shortly after the evaporated milk has been added slowly to the hot coffee.

2.2 Defects in evaporated milk

2.2.1 Flavour

The flavour defects which may occur in evaporated milk are usually unlike those commonly occurring in fresh beverage milk. Probably the most common flavour defect in evaporated milk is that which seems to be associated with progressive age-darkening or browning of the product. Terms such as slightly acid, stale coffee, old, sour and strong suggest the nature of the defect. The caramel flavour connotes a pleasant, appetizing taste sensation which is definitely lacking in the defect associated with age-darkening of evaporated milk. This flavour defect is easily detected.

The off-flavour is accompanied by only a slight odour suggesting staleness. The underlying taste reaction of the age darkened evaporated milk is acid.

2.2.2 Body and texture

Fresh evaporated milk is remarkably free of body and texture defects. However, when evaporated milk is held for a long period of time or under adverse conditions, the following body and texture defects may be encountered:

2.2.2.1 Butter/fat separation. This defect appears as a layer (up to 1 cm or more thick) of heavy cream at the top of the can. Among the causes of this defect are inadequate homogenization, high storage temperature, long storage period and improper handling while in storage.
2.2.2.2 *Curdy*: Curdy evaporated milk may be noted by the presence of many coagulated particles interspersed throughout the milk or by a continuous mass of coagulum. It is chiefly associated with the protein rather than the fat. It is a serious economic defect. This condition is due mainly to the abnormally low heat coagulation point of the end product and could not withstand the sterilization process.

2.2.2.3 *Feathering*: The feathering of evaporated milk in hot coffee cannot be foretold by macroscopic examination but by actually testing the milk in hot coffee. It has been postulated that the formation of curd when evaporated milk is added to coffee is due entirely to an excess of viscosity.

2.2.2.4 *Gassy*: Gassy evaporated milk is rather uncommon. The defect is manifest by bulged cans and sometimes by a hissing sound of escaping air when the can is punctured.

2.2.2.5 *Grainy*: A grainy evaporated milk is the one lacking smoothness and uniformity throughout. Such milk seems coarse. It is often associated with an excessively heavy, viscous body. The judge must bear in mind that grainy evaporated milk does not actually contain "grains" of sediment settled in the container. Neither does such milk contain curds or lumps of butter.

2.2.2.6 *Low viscosity*: A low viscosity evaporated milk may be noted by its milk like consistency. This defect is discriminated against as it connotes inadequate condensation.

2.2.2.7 *Sediment*: The sediment resulting from settling of leukocytes, disintegrated cells, denatured protein and foreign material of more or less of a colloidal nature is usually darker in colour than the evaporated milk. Since this sediment is readily miscible it may be seen only when a can, undisturbed for sometime, is emptied slowly.

The other type of sediment noted in evaporated milk is the result of the crystallisation of some of the calcium and magnesium salts as Ca₃ (PO₄)₂ and Mg₃ (PO₄)₂. This gritty sediment formation accompanies ageing of the evaporated milk. They are found in the bottom of the container where they may be noted especially when the contents are emptied.

2.2.3 *Colour*

In judging evaporated milk two possible colour defects may be encountered, viz. too light in colour and too dark in colour. Too light colour is not a serious defect although it is definitely not desired. The brown discoloration in evaporated milk associated with high sterilisation temperature, high storage temperature and age is a serious defect in evaporated milk.

3. **SWEETENED CONDENSED MILK**

Since sweetened condensed milk contains a sufficiently high percentage of sugar for its preservation, the flavour is pronouncedly sweet. Beyond this intense sweetness, the flavour should be clean and pleasant with a slight trace of mild caramel as an aftertaste.
3.1 Procedure for examination

A definite routine enables the judge to make the best use of the available time with
the assurance that the examination is complete when finished (Seehafer, 1967).

a. Appearance of the container should be as bright as new tin as the can has not
been subjected to the high heat treatment of sterilization.

b. The surface of the product should have the same intensity of colour as the
underlayer and should be uniform in consistency with no indication of lumps, free fat
or screen formation.

c. Colour of the product should be uniform throughout. Observe if the milk has a
greenish white creamy or a brownish colour.

d. Viscosity desired is one which is obviously not "thin" but resembling to a marked
degree that of medium - heavy molasses. In grading sweetened condensed milk, the
judge must bear in mind that a desirable sweetened condensed milk pours like
molasses and, when poured, seeks its own level leaving no trace of the folds on the
surface.

e. Flavour should be observed both for the textural and taste sensations. Register the
relative smoothness of the product as a whole and the fineness of the grain by
pressing the sample against the palate with the tongue.

3.2 Defects of sweetened condensed milk

3.2.1 Flavour

3.2.1.1 Metallic; The metallic flavour in sweetened condensed milk is chemical rather than
bacterial in nature and is usually traceable to copper contamination.

3.2.1.2 Rancid; It occurs rather infrequently and resembles butyric acid. Rancid flavour
increases in intensity with age.

3.2.1.3 Strong; It is a flavour defect, which is suggestive of caramelised sugar and is usually
accompanied by browned tint to the natural colour.

3.2.2 Body and texture

Condensed milk, having a high percentage of sugar has a relatively heavy body
somewhat like normal molasses. Also, it usually has a smooth, uniform texture. However,
the product may have certain body and texture defects such as buttons or lumpiness, fat
separation, gassiness, sandiness, sediment, thickening etc (Gupta and Patel, 1978).

3.2.2.1 Buttons/lumpy; It is a body defect which is characterised by the presence of round
and firm lumps, with stale odour, at the surface of the product. Buttons result from enzymic
action following mould growth.
Sensory evaluation of concentrated milks

3.2.2.1 *Buttons/lumpy*: It is a body defect which is characterised by the presence of round and firm lumps, with stale odour, at the surface of the product. Buttons result from enzymic action following mould growth.

3.2.2.2 *Sandy, rough, graney, granular*: These terms are used to describe sweetened condensed milk which contains oversized lactose crystals. The solid particles are of such size that the product lacks smoothness and a grittiness is noticeable as the sample is being tasted.

3.2.2.3 *Settled*: It is used to describe the condensed milk in which a definite settling of sugar crystals has occurred.

3.2.2.4 *Thickened*: This defect is manifest by a gel formation which gives the product the appearance of a solid rather than a liquid. The defect varies markedly in its intensity from a slight jelly to a firm custard consistency.

SELECTED REFERENCES


### ANNEXURE -1

**Evaluation card for Sweetened Condensed Milk**

<table>
<thead>
<tr>
<th>Name</th>
<th>Code No.</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
</table>

A) Score the sample for different characteristics. Indicate the degree of defects, if any, encircling the applicable one and deduct accordingly from the characteristic score.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Maximum score (2)</th>
<th>Minimum score for each attribute (3)</th>
<th>Sample Score (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Package appearance</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Colour and appearance</td>
<td>15</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Body and Texture</td>
<td>35</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Flavour</td>
<td>45</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** If the sample scores less than the minimum for any characteristic, it is to be rejected.

B) **Degree of Defects**

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>DEFECT</th>
<th>DEGREE OF DEFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Suspicion</td>
<td>Definite</td>
</tr>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Package appearance</td>
<td>Improper seal / rust spot/ soiled / duff surface</td>
<td>1</td>
</tr>
<tr>
<td>Colour and appearance</td>
<td>Browning</td>
<td>1</td>
</tr>
<tr>
<td>Body and Texture</td>
<td>Mould Buttons</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Fat separation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Thickened</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sandy/coarse/ mealy/ heavy</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Settled</td>
<td>1</td>
</tr>
<tr>
<td>Flavour</td>
<td>Caramelized</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Rancid / tallowy</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Metallic</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Fruitness</td>
<td>2</td>
</tr>
</tbody>
</table>

**Grading:** After computation of data, recorded in the above table by the panelists, the following grade should be awarded:

<table>
<thead>
<tr>
<th>Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 and above</td>
<td>Excellent</td>
</tr>
<tr>
<td>80-89</td>
<td>Good</td>
</tr>
<tr>
<td>60-79</td>
<td>Fair</td>
</tr>
<tr>
<td>59 and below</td>
<td>Poor</td>
</tr>
</tbody>
</table>

**Source:** Method for Sensory Evaluation of Sweetened Condensed Milk. IS : 10030 - 1981.
SENSORY ATTRIBUTES OF DRIED MILKS
AND THEIR EVALUATION

Alok Jha* and R. S. Mann
Division of Dairy Technology
N.D.R.I., Karnal - 132 001

1. INTRODUCTION

Evaluation of milk powder, whole or skimmed, on the basis of its sensory characteristics plays an important role in its marketing. Those who buy milk powder give prime consideration to its sensory properties, such as flavour and appearance for its acceptability (Prentice, 1972). The sensory examination of milk powder assumes great significance in our country in particular, not only because skim milk powder (SMP) is manufactured in large quantities at feeder balancing plants in the flush season for its subsequent reconstitution during the lean period so as to maintain the milk supply to the needy areas but also as it has become an important export commodity (Bodyfelt et al., 1988).

2. DRY WHOLE MILK

In judging whole milk powder (WMP) for flavour one first classifies the product for flavour as good, fair or poor.

2.1 Flavour

The flavour of dry whole milk should be clean, rich, sweet and pleasant. Frequently, dry milk may be unduly criticised as having a 'heated' or a 'cooked' taste. This may be expected or even desired. Often, dry milk gradually loses its sweet, fine, appetizing flavour upon aging, thus becoming more or less off flavoured. The more frequently occurring flavour defects of dry whole milk are discussed below.

2.1.1 Stale, storage, old: This appears to be a characteristic age defect associated with protein. When the defect is intense it may be accompanied by a darkening of the product.

2.1.2 Rancid: Rancid dry whole milk has a bitter, soapy, unclean taste which is persistent after the sample has been expectorated. The reason may be insufficient forewarning temperature to inactivate the lipase enzyme.

2.1.3 Oxidized/tallowy: It is the most troublesome flavour defect of dry whole milk. Many factors affect the development of this defect such as temperature, light, moisture, acidity, metallic salts, condensation and type of packaging.

2.1.4 Scorched: This flavour is produced in products which have been subjected to excessive heat during the drying stage or have been permitted to remain in the drying chamber for too long a period of time. It is usually accompanied by a large number of
scorched specks in the product and sometimes by a dark discolouration typical of overheating.

2.2 Physical characteristics of WMP

Two defects pertaining to the body and texture of dry whole milk are lumpy and caked.

2.2.1 Lumpy: A lumpy powder definitely lacks homogeneity. Hard lumps ranging in size from a grain of wheat upwards may be interspersed throughout. This defect is found more frequently in the spray process product. Lumps result from insufficient drying, drippage from spray nozzles or exposure to moisture laden air.

2.2.2 Caked: Usually this defect is not encountered in dry whole milk. When it does occur, the product loses its powdery consistency and becomes a rock like solid. When the solid mass is broken up, it remains in chunks, thus failing to return to the original powder state. This defect is serious since such milk solids have lost their sales value for human consumption.

2.3 Colour of WMP

Normal dry whole milk is light yellow in colour but varies reasonably with the colour in the fat from a creamy white to a deep yellow. The defects of colour in dry whole milk are as follows:

2.3.1 Browned or darkened: This defect is associated with age. When the defect is present, the normal creamy colour has been replaced by a distinct brown. The defect is usually associated with an old, stale flavour.

2.3.2 Scorched: Discolouration due to burning of the milk solids is usually associated with the roller process. The powder may vary from light to dark brown.

2.3.3 Lack of uniformity: This defect may be due to either partial discolouration (browning) after packaging or to partial scorching during the manufacturing process.

3. SKIM MILK POWDER (SMP)

3.1 Flavour of SMP

The flavour of high quality nonfat dry milk is similar, when reconstituted, to that of fresh skim milk. Due to its low fat content, it does not possess the rich flavour of high fat milk powder. The flavour is clean, sweet and pleasant and may have a slightly cooked or heated note. The chief flavour defects of nonfat dry milk are as follows:

3.1.1 Stale, storage, old: This flavour defect is the chief one of nonfat dry milk. In this product the off-flavour is even more "quick" and distinct than in dry whole milk. Usually the
flavour defect is accompanied by a darkening of the powder. The old, stale flavour develops usually more intensely in spray process than in roller process powder.

3.1.2 Scorched: As in dry whole milk, this flavour is produced in products which have been subjected to abnormally high heat during processing.

3.1.3 Oxidized, tallowy: Nonfat dry milk contains a small percentage of fat which oxidizes under some conditions yielding the oxidized or tallowy flavour. A tallowy product has a pronounced odour whereas stale powder does not have a very intense odour.

3.2 Physical characteristics of SMP

Nonfat dry milk prepared by spray process is very fine in particle size and uniform throughout. Instead of being flour like in texture, instant SMP is more or less granular. The product pours readily somewhat like that of corn meal. The highly hygroscopic, light, almost air-borne dust of normal spray process SMP is lacking.

3.3 Colour of SMP

Nonfat dry milk should be uniform in colour throughout showing the absence of foreign specks and burnt solids. The product should have a creamy white or light yellow colour which varies slightly in intensity with the season of the year. Upon ageing under certain conditions SMP tends to darken. When this defect occurs the light yellow colour has given way to a definite brown. Spray process powder appear to be more susceptible to age darkening and to a greater intensity than roller-process powder.

4. MALTED MILK

4.1 Flavour

Malted milk, being composed in large part of maltose and dextrose, has a definitely sweet taste. It should have a distinct flavour of malt. The product should be judged for its lack of malt flavour and for oxidized flavour defect.

4.2 Body and texture

Malted milk has a coarse and grainy texture unlike the fine texture of spray dried milk. While judging, product must be examined for possible stickiness and formation of cakes because of its affinity for water.

5. INDUSTRY STANDARDS FOR GRADRES OF DRY MILK

The American dry milk industry has adopted standards for dry whole milk and nonfat dry milk. These are based on product quantity and provide two grades for each process as follows:
Process | Grades
--- | ---
**Dry Whole Milk**
Spray
Gas packed | Premium, extra
Bulk | Extra, Standard

**Roller**
Bulk | Extra, Standard

**Nonfat Dry Milk**
Spray | Extra, Standard
Roller | Extra Standard

The tolerances permitted for flavour and appearance in Premium and Extra Grades are as follows: "Premium and Extra grade dry whole milk shall be free from lumps except those that break up readily under slight pressure. The reconstituted product shall have a sweet and desirable flavour but may possess the following flavour to a slight degree: Chalky, cooked and feed."

The tolerance for the standard grade are "Standard grade dry whole milk shall be free from lumps except those that break up readily under slight pressure. The reconstituted product shall possess a fairly desirable flavour but may possess a bitter, oxidized, stale, storage, utensil and scorched flavour to a slight degree and a chalky and feed flavour to a definite degree."

**6. METHOD OF RECONSTITUTING DRY MILK FOR FLAVOUR EXAMINATION**

Generally in examining dry milk for odour and taste, the product is reconstituted on the basis of the original concentration. The American Dry Milk Institute (ADMI) recommends examination of dry milk odour immediately after the containers are opened and again for odour approximately one hour after the sample has been reconstituted. The judge must be mindful of the fact that freshly prepared fluid milk made from water and food quality dry whole milk often possess a slightly chalky, watery or slightly cooked taste. Hence permitting a short storage period for blending of flavours after reconstituting the product should aid the judge in determining more accurately the true flavour.

**SELECTED REFERENCES**


ANNEXURE - I
Evaluation Card for Milk Powder

Name........................................ Dated.........................
Code No................................... Time.............................

A. Score the sample for different characteristics. Indicate the degree of defects, if any, encircling, the applicable one and deduct accordingly from the attribute score.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Max Score</th>
<th>Minimum for each attribute</th>
<th>Sample Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>i) Package Appearance</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>ii) Appearance of Dry Product</td>
<td>15</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>iii) Appearance of reconstituted milk</td>
<td>15</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>iv) Body and texture of reconstituted milk</td>
<td>20</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>v) Flavour of reconstituted milk</td>
<td>45</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>

Note: If the sample score less than the minimum for any characteristic, it is to be rejected.

B. Degree of Defects

<table>
<thead>
<tr>
<th>CHARACTERISTICS</th>
<th>DEFECT</th>
<th>DEGREE OF DEFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>i) Appearance of package</td>
<td>Soiled surface unscaled</td>
<td>1</td>
</tr>
<tr>
<td>ii) Appearance of dry product</td>
<td>Caked/brown particles</td>
<td>2</td>
</tr>
<tr>
<td>iii) Appearance of reconstituted milk</td>
<td>Lumpy brown</td>
<td>1</td>
</tr>
<tr>
<td>iv) Flavour</td>
<td>Oxidized/stale/rancid Chalky/acid/neu-tralizer/salty Metallic/cooked/scorched Weedy/bitter/foreign</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

1. INTRODUCTION

Ice-cream is a delicious, wholesome nutritious frozen dairy food. It has evolved over a period spanning about five centuries. The great technological progress made in the field of dairying in the nineteenth century such as the development of centrifugal separator, mechanical refrigeration, better understanding of chemistry and bacteriology provided stimulus to the development of a large ice-cream industry that we see today. Ice-cream has occupied a unique place in the diet of western people and is gaining steadily in popularity all over the world. For instance, the annual production of ice-cream in USA has reached more than 3770 million litres. Other countries ranking high in annual production of Ice-cream and related products are Japan: (750 million litres), Canada (476), Australia (331), and UK (218). India is the third largest producer of ice-cream in the world with production of over 513 million litres annually. It has been estimated that 0.6 per cent of total milk production in our country is utilized for making Ice-cream and Kulfi. The Ice-cream industry in India is expanding very fast witnessing an estimated growth rate of 25 to 35 per cent per year. Production of excellent quality Ice-cream is essential to the success and progress of the ice-cream industry. The quality of the ice-cream is judged by the consumer on the basis of its sensory attributes i.e. flavour, body and texture, melting behaviour, colour and the appearance of package or container. Besides, the product should also comply with legal standards with regard to its chemical composition and bacteriological quality. Ice-cream not possessing desirable sensory properties cause diminished consumer goodwill, sales and income to the manufacturer.

2. FACTORS AFFECTING SENSORY ATTRIBUTES OF ICE-CREAM

The quality of ice-cream depends not only on composition of ice-cream, but also on the quality of raw materials used, methods of manufacture, distribution and sale of the product—these factors are under the control of the ice-cream maker. A full knowledge of the factors by which the quality may be attained or controlled is therefore, essential for the production of ice-cream possessing desirable sensory attributes.

There are many differing concepts of 'perfect ice-cream'. Individual preferences can cause large variations in what people consider to be ice-cream of highest quality. Some prefer ice-cream with a low fat content, while others will want high fat. Some will like very smooth textured ice-cream, others may prefer it be not too smooth. Variations exist in the required sweetness level and so on. Therefore, desirable sensory attributes of ice-cream can be best explained by giving details of defects and faults which may be found in ice-cream, and show how these faults occur and how they may be overcome.
3. JUDGING OF ICE-CREAM

The available methods of determining the sensory attributes of ice-cream rely mainly on tasting and using a score-card. Such score-cards give maxima for various aspects of the ice-cream quality such as flavour, texture, body and colour. The American Dairy Association has stipulated a score-card for ice-cream, which carries a maximum score of 10 for flavour, 5 for body and 5 for colour and appearance, 3 for melting quality and 2 for bacterial content. The recommended scoring guide is given in Table 1.

Table 1. The ADSA scoring guide for sensory defects of ice-cream

<table>
<thead>
<tr>
<th>Intensity of Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criticisms</td>
</tr>
<tr>
<td>Flavour</td>
</tr>
<tr>
<td>Acid (sour)</td>
</tr>
<tr>
<td>Cooked</td>
</tr>
<tr>
<td>Flavoured</td>
</tr>
<tr>
<td>Lacks flavouring</td>
</tr>
<tr>
<td>Too high</td>
</tr>
<tr>
<td>Unnatural</td>
</tr>
<tr>
<td>Lacks fine flavour</td>
</tr>
<tr>
<td>Lack freshness</td>
</tr>
<tr>
<td>Metallic</td>
</tr>
<tr>
<td>Old ingredient</td>
</tr>
<tr>
<td>Oxidized</td>
</tr>
<tr>
<td>Rancid</td>
</tr>
<tr>
<td>Salty</td>
</tr>
<tr>
<td>Storage</td>
</tr>
<tr>
<td>Sweetener</td>
</tr>
<tr>
<td>Lacks</td>
</tr>
<tr>
<td>Too high</td>
</tr>
<tr>
<td>Syrup flavour</td>
</tr>
<tr>
<td>Whey</td>
</tr>
<tr>
<td>Body and texture</td>
</tr>
<tr>
<td>Coarse/Icy</td>
</tr>
<tr>
<td>Crumbly (brittle, friable)</td>
</tr>
<tr>
<td>Fluffy (foamy)</td>
</tr>
<tr>
<td>Gummy (pasty, sticky)</td>
</tr>
<tr>
<td>Sandy</td>
</tr>
<tr>
<td>Soggy (heavy, pudding-like)</td>
</tr>
<tr>
<td>Weak (watery)</td>
</tr>
</tbody>
</table>
Table 2. Flavour defects of ice-cream, their causes and remedies

<table>
<thead>
<tr>
<th>Defects</th>
<th>Cause</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. High flavour</td>
<td>i) Presence of large amount of flavouring material</td>
<td>i) Adding right amount of flavouring material</td>
</tr>
<tr>
<td>B. Low flavour</td>
<td>i) Presence of insufficient amount of flavouring material</td>
<td>i) -do-</td>
</tr>
<tr>
<td>C. Acid flavour</td>
<td>i) Presence of an excessive amount of lactic acid (developed)</td>
<td>i) Using fresh dairy products ii) Prompt, efficient cooling of mix iii) Avoiding prolonged storage of mix at high storage temperature</td>
</tr>
<tr>
<td>D. Bitter flavour</td>
<td>i) Use of inferior products</td>
<td>i) Using true flavour extract. ii) Avoiding use of dairy products stored for long period at low temperatures iii) Using products free from off flavour</td>
</tr>
<tr>
<td>E. Cooked flavour</td>
<td>i) Overheating the mix ii) Using overheated concentrated dairy products</td>
<td>i) Carefully controlling pasteurization process. ii) Using conc. products free of cooked flavour</td>
</tr>
<tr>
<td>F. Flat flavour</td>
<td>i) Use of insufficient flavour, sugar or milk solids</td>
<td>i) Using right amount of these ingredients</td>
</tr>
<tr>
<td>G. Metallic flavour</td>
<td>i) Copper contamination ii) Bacterial action</td>
<td>i) Avoiding copper contamination of mix during processing. ii) Avoiding use of products having metallic flavour.</td>
</tr>
<tr>
<td>H. Unnatural flavour</td>
<td>i) Flavour not typical to ice cream</td>
<td>i) Using high quality flavouring products. ii) Using high quality dairy and non-dairy products.</td>
</tr>
</tbody>
</table>

When ice-cream is being judged organoleptically it is important that the serving temperature should be correct. If it is too cold the palate will be deadened, and it will not be possible either to enjoy the ice-cream or to judge any of its sensory characteristics. If it is too warm it will have melted partially judging of body and texture will be almost impossible. A consumer judges the quality or sensory attributes of ice-cream on the basis of several characteristics—these are flavour, body, texture and appearance of the product and the package.

3.1 Flavour

Ice-cream is a mixture of fat, sugar and milk solids-not-fat together with added flavour and colour. An increase in total solids increases the richness of the ice-cream and normally improves the flavour, texture and body. Some if these ingredients have marked flavour, others are more nearly neutral or bland. However, the flavour of no single ingredient should predominate, but each should blend together to form a harmonious whole, creamy sweet sensation with a slight flavour, leaving a pleasant after taste which must not be excessive. Many possible flavour defects may arise due to use of faulty ingredients. The more common flavour defects are given in Table 2.
Table 3. Body and texture defects of ice cream

<table>
<thead>
<tr>
<th>Name</th>
<th>Causes</th>
<th>Prevention</th>
</tr>
</thead>
</table>
| A. Crumbly body  | i) Low T.S. content  
ii) Insufficient stabilizer  
iii) Excessive overrun  
iv) Improper homogenization | i) Increasing T.S. content  
ii) Increasing stabilizer  
iii) Decreasing overrun  
iv) proper homogenization |
| B. Soggy body    | i) Low overrun  
ii) High sugar content  
iii) Excessive amount of stabilizer | i) Proper overrun  
ii) Optimum suggest content  
iii) Right amount of stabilizer |
| C. Shrunken body | (The ice-cream shrinks away from the sides and top of the container.)  
   i) Fluctuating temperatures during storage  
   ii) Excessive overrun  
   iii) Protein instability  
   iv) Rough transportation | i) Avoiding fluctuating temperature during storage  
   ii) Reducing overrun  
   iii) Avoiding high acidity in mix  
   iv) Avoiding rough transportation |
| D. Weak body     | i) Low T.S. content  
ii) Insufficient stabilizer | i) Increasing T.S. content  
ii) Increasing stabilizer |
| E. Buttery texture | i) Improper homogenization  
ii) High fat content  
iii) Slow freezing | i) Proper homogenization  
ii) Optimum fat content  
iii) Fast freezing |
| F. Coarse or ice texture | i) Low T.S. cont  
   ii) Insufficient stabilizer  
   iii) Slow freezing  
   iv) Slow hardening  
   v) Insufficient ageing  
   vi) Heat shocking  
   vii) Prolonged storage | i) Increasing T.S. content  
   ii) Increasing stabilizer  
   iii) Fast freezing  
   iv) Fast hardening  
   v) Sufficient ageing  
   vi) Avoiding heat shocking  
   vii) Avoiding prolonged storage |
| G. Fluffy texture | i) Excessive overrun  
ii) Low T.S. content  
iii) High emulsifier content | i) Decreasing overrun  
ii) Increasing T.S. content  
iii) Decreasing emulsifier content |
| H. Sandy texture | i) High M.S.N.F. (Lactose) content  
   ii) Fluctuating temp. in retail cabinets  
   iii) Long storage Period | i) Decreasing M.S.N.F. (Lactose) content  
   ii) Avoiding fluctuating temperatures in retail cabinets  
   iii) Reducing storage periods |

3.2 Body and texture

Both the body and texture of ice-cream may be determined readily by the senses of sight and touch. The desired body in ice-cream is that which is firm, has substance, responds readily to dipping and melts down at ordinary temperatures to a creamy consistency. The desired texture is that which is fine, smooth, velvety and carries the appearance of creaminess throughout. The possible body and texture defects which may be encountered in ice-cream are presented in Table 3.

3.3 Melting quality

High quality Ice-cream should show little resistance toward melting when it is exposed to room temperature. During melting the mix should drain away as rapidly as it melts and form a smooth, uniform homogeneous liquid. Any variations from this behaviour
may lead the consumer to be suspicious of its quality. The defects in melting quality frequently observed in judging ice-cream are given in Table 4.

Table 4. Melting quality defects of ice-cream

<table>
<thead>
<tr>
<th>Name</th>
<th>Causes</th>
<th>Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Curdy meltdown</td>
<td>i) High acidity of mix.</td>
<td>i) Using fresh dairy products</td>
</tr>
</tbody>
</table>
| b) Slow melting    | i) Excessive amount of stabilizer  
                         ii) Improper homogenization. | i) Reducing the amount of stabilizer.  
                                            ii) Proper homogenization. |
| c) Whey leakage    | i) Poor quality dairy products  
                         ii) Improperly balanced mix.  
                         iii) Improperly stabilized mix. | i) Using fresh dairy products  
                                            ii) Balancing the mix properly.  
                                            iii) Using more effective stabilizer. |
| d) Foamy melt down | i) Excessive overrun.        | i) Reducing overrun.          
                         ii) Excessive amount of emulsifier. | ii) Reducing amount of emulsifier. |

3.4 Colour

The colour of the ice-cream should be attractive and pleasing. The ideal colour is characteristic of the flavour, true in shade and neither too pale nor too intense. For example, vanilla ice-cream should have a creamish yellow to white colour. Uniform, natural colour is desirable in ice-cream. Excessive colour is the result of adding too much artificial colour to the mix. An uneven colour results if the colour is not properly added and also if care is not exercised when changing flavours. An unnatural colour is caused by (a) carelessness in adding the colour, (b) improper use of colours, or (c) use of foreign materials.

4. CONCLUSION

Therefore, an excellent quality of Ice-cream can be made only from good mix ingredients properly balanced to produce a desirable composition along with proper processing, freezing, hardening and distribution, under proper sanitary conditions. All these factors are important and must be carefully controlled if the Ice-cream having desirable sensory attributes is to be produced. It must be remembered that product inferiority constitutes one of the greatest menaces to the success and progress of the ice-cream industry. The consumer has learnt to depend upon Ice-cream as a safe, enjoyable, energy-giving, nourishing & refreshing food.

REFERENCES

1. INTRODUCTION

Cultured milk products, which include dahi, yoghurt, lassi, buttermilk, shrikhand, sour cream and kefir, play an important role in the dairy industry. Their low pH and extended shelf life make cultured milk products particularly relevant to commercial production in tropical countries.

While sensory attributes are very important determinants of the acceptability of cultured milk products, their sensory evaluation has not progressed to the same extent as the art and science of sensory discrimination for milk and many other manufactured milk products. Generally, sensory evaluation of commercial fermented milk and cream products has frequently involved more of a comparison of the products of current manufacture with those made previously. This procedure, however may tend to result in a progressively lower quality product.

2. COMMON ATTRIBUTES OF CULTURED MILK PRODUCTS

2.1 Flavour

Cultured milk products should impart a pleasing bouquet flavour, which results from the overall blend of a delicate, diacetyl odour and a distinctly clean, acid taste. Once the aroma and taste characteristics of a good cultured product are fixed in the mind of the evaluator they are not easily forgotten. Sometime there is possibility of occurrence of one or more of several off flavours, such as bitter, cheesy, lack of desired aroma, lack or flavour and high acid.

2.2 Body and texture

Before being shaken the body of a good, properly cultured product should appear firm or solid and generally be uniform in appearance. It should only show a few beads of whey exuded from the surface. The mix sample should appear smooth, somewhat resembling rich cream, no curd particles or lumps should appear when in is spread in a thin layer in a glass surface or diluted with water. Some of the more common body defects of cultured milk products are described in the following paragraphs.

2.2.1 Curdy: A curdy body tends to lack uniformity, smoothness or homogeneity. The curd particles may be sufficiently large to be readily observed upon pouring or so small in size that close examination is necessary to see the featherns curds.
2.2.2 Lumpy: A "lumpy" body is often an aggravated case of curdy consistency; the particle size is larger in the lumpy defect.

2.2.3 Gassy: A "gassy" product is denoted by excessive gas bubbles (CO), or by streaks in the coagulum due to the rise of gas bubbles to the surface. If accompanied by whey separation, a gassy sample will whey-off at the bottom or at the centre of the container.

2.2.4 Ropy: A rosy product tends to stretch or string-out when poured. Sometimes the defect is so pronounced that the product strings out like a thin syrup or mucous substance.

2.2.5 Wheying-off: This defect is manifest by a shrunken curd or coagulum and the presence of liberated or "free whey" in areas around the side and on the surface of the container.

3. YOGHURT

Yoghurt is a quickly curdled milk based product with little or no alcohol content. It results from the associative growth of Lactobacillus bulgaricus and Streptococcus thermophilus in warm milk (29-45°C). Typical yoghurt is characterized by a smooth, viscous gel, with a taste of sharp acid and a green or green apple flavour; some yoghurt exhibit a heavy consistency that closely resembles custard or milk pudding; by contrast, other yoghurt are purposely soft-bodied and essentially drinkable. Different types of yoghurt sold in the USA and their characteristics are given in Table 1.

Table 1 Characteristics of the various styles of flavoured yoghurts in U.S.A.

<table>
<thead>
<tr>
<th>Yoghurt style (Type)</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Swiss-Style (French-Pristined, or Preblended)</td>
<td>Pre-cultured yogurt base and fruit or berry flavouring (15-25%) blended prior to packaging.</td>
</tr>
<tr>
<td>2 Sundae-Style (Fruit-on-bottom)</td>
<td>Flavouring (15-25%) added to the container, yogurt base added to top of flavouring.</td>
</tr>
<tr>
<td>a. Eastern-type</td>
<td>No colouring agent, flavouring, or sweetener added to yogurt base (milk base is white).</td>
</tr>
<tr>
<td>b. Western type</td>
<td>Colouring agent, flavor extract, or concentrate and/or sweetener added to yogurt base (milk base is color of given flavor).</td>
</tr>
<tr>
<td>c. Fruit-on-top</td>
<td>Yogurt cups filled in a manner so that flavouring material is on top portion of container.</td>
</tr>
<tr>
<td>3 Extract flavoured (or concentrates)</td>
<td>Flavour extracts and or concentrates are sole source of flavour plus sweetener(s) (i.e., coffee, chocolate, lemon etc.)</td>
</tr>
<tr>
<td>4 Frozen Product Form</td>
<td></td>
</tr>
<tr>
<td>a. Soft serve</td>
<td>Served as cones, dish, or sundaes.</td>
</tr>
<tr>
<td>b. Hard frozen</td>
<td>Pint and quart size</td>
</tr>
<tr>
<td>c. Novelties</td>
<td>On-a-stick, coated bars, &quot;push-ups&quot;</td>
</tr>
<tr>
<td>d. Yogurt pies</td>
<td>In &quot;pie&quot; crusts.</td>
</tr>
<tr>
<td>5 Miscellaneous types</td>
<td>A variant of the sundae-style Western type: A firm, flavored yogurt with additional flavoring cascading over its exterior when emptied up-side down.</td>
</tr>
</tbody>
</table>
Sensory attributes of fermented milks

3.1 Desirable attributes of yoghurt

Yoghurt should be smooth, viscous gel, with a characteristic taste of sharp acid and a green or green apple flavour. The typical acetaldehyde flavour of plain yoghurt is achieved through a symbiotic bacterial relationship in fenced by such factors as (1) temperature of incubation, (2) amount of inoculum (3) period of incubation, (4) source of culture, (5) heat treatment of yoghurt base and (6) pH of the finished products. The flavour of plain yoghurt is somewhat unique and unlike that encountered in any other type of fermented milk. The flavour components of plain yoghurt flavour include acetaldehyde acetic acid, diacetyl and several volatile fatty acids.

3.2 Defects in yoghurt

3.2.1 Plain yoghurt

Colour and appearance consideration for plain yoghurt are rather simple and straightforward, compared to the complexities of flavored yoghurt. Generally, the appearance of plain yoghurt should convey a smooth, homogenous, moderately firm gel or custard-like body and texture and a uniform off-white color. The more common color and appearance defects of plain yogurt are reviewed here.

3.2.1.1 Free whey : Wheyed-Off (Syneresis) This defect is manifest by a shrunk curd or coagulum and the presence of liberated or "free whey" in areas around the side and on the surface of the container.

3.2.1.2 Gel-like : This condition may be considered as both an appearance and a body and texture defect. The term "gel-like" is used to describe the appearance of excessive product firmness, or a severe gelatin (liver like) consistency.

3.2.1.3 Shrunk : Occasionally in yoghurt, the gel or coagulum tends to shrink in size within the container (or pull away from the carton side wall); this leaves the impression of reduced or "shrunk" contents. Quite often, free whey will fill the void that results from this "shrinking" of the coagulum.

3.2.1.4 Surface Growth : Probably the most serious defect of yoghurt appearance. This defect consists of visible colonies of yeast and/or mold growth on the top surface of the yoghurt.

3.2.2. Body and texture defects

3.2.2.1 Grainy : In the instance of "graininess," the product lacks the desired smoothness and uniformity of appearance. Small particles of a grit or grain size may actually be visible; graininess is quite often detectable by mouthfeel.

3.2.2.2 Ropy : Aropy product tends to stretch or "string-out" when poured. Sometimes the defect is so pronounced that the product "strings-out" like a thin syrup or mucous substance.
3.2.2.3 Too Firm: When the body of plain yoghurt is considered "too firm", it conveys the impression of being too rigid or resistant to mastication when placed in the mouth. Also, a too firm body is often apparent by visually examining a side profile of a spoonful of product. Firm or rigid edges can be noted, rather than a more preferred "soft rounding" impression of a spoonful of product.

3.2.2.4 Weak: A weak body defect is the exact opposite of too firm; the product consistency conveys the distinct impression that it would probably be easier to consume the product as a beverage than to "spoon" it. Viewed from side profile, the product may appear practically level in the spoon, or it may spill over the lip of the spoon. For a drinkable style yoghurt, a weak body is a prerequisite.

3.3. Procedure for yoghurt evaluation

A score card for swiss-style flavoured yoghurt (fig. 1) developed and adopted by the Committee on Evaluation of Dairy Products of the American Dairy Science Association carries maximum scores for different attributes (Table 2) and can be used as per the guidelines given in Table 3. This score card was co-operatively designed through the suggestions and efforts of ingredient suppliers and commercial yoghurt manufacturers.

Table 2. Maximum scores for the sensory attributes of yoghurt

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Maximum score</th>
<th>Normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavour</td>
<td>10</td>
<td>1-10</td>
</tr>
<tr>
<td>Body and texture</td>
<td>5</td>
<td>1-3</td>
</tr>
<tr>
<td>Appearance</td>
<td>5</td>
<td>1-5</td>
</tr>
<tr>
<td>Product acidity</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Container and closure</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3. Scoring guide for the sensory defects of Swiss-style yoghurt

<table>
<thead>
<tr>
<th>Criticism</th>
<th>Intensity of Defect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slight</td>
</tr>
<tr>
<td>Flavour</td>
<td></td>
</tr>
<tr>
<td>Acetaldehyde (green)</td>
<td>9</td>
</tr>
<tr>
<td>Acid (too high)</td>
<td>9</td>
</tr>
<tr>
<td>Acid (too low)</td>
<td>9</td>
</tr>
<tr>
<td>Bitter</td>
<td>9</td>
</tr>
<tr>
<td>Cooked</td>
<td>9</td>
</tr>
<tr>
<td>Foreign</td>
<td>5</td>
</tr>
<tr>
<td>Lacks fine flavour</td>
<td>9</td>
</tr>
<tr>
<td>Lacks flavouring</td>
<td>9</td>
</tr>
<tr>
<td>Lack freshness</td>
<td>8</td>
</tr>
<tr>
<td>Lacks sweetness</td>
<td>9</td>
</tr>
<tr>
<td>Old ingredient</td>
<td>7</td>
</tr>
</tbody>
</table>
### Sensory attributes of fermented milks

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidized/metallic</td>
<td>6</td>
</tr>
<tr>
<td>Rancid</td>
<td>4</td>
</tr>
<tr>
<td>Too high flavouring</td>
<td>9</td>
</tr>
<tr>
<td>Too sweet</td>
<td>9</td>
</tr>
<tr>
<td>Unclean</td>
<td>6</td>
</tr>
<tr>
<td>Unnatural flavoring</td>
<td>8</td>
</tr>
<tr>
<td>Body and texture</td>
<td></td>
</tr>
<tr>
<td>Gel-like</td>
<td>4</td>
</tr>
<tr>
<td>Grainy/gritty</td>
<td>4</td>
</tr>
<tr>
<td>Ropy</td>
<td>3</td>
</tr>
<tr>
<td>Too firm</td>
<td>4</td>
</tr>
<tr>
<td>Too firm</td>
<td>4</td>
</tr>
<tr>
<td>Weak/too thin</td>
<td>4</td>
</tr>
<tr>
<td>Appearance</td>
<td></td>
</tr>
<tr>
<td>Atypical colour</td>
<td>4</td>
</tr>
<tr>
<td>Colour leaching</td>
<td>4</td>
</tr>
<tr>
<td>Excess fruit</td>
<td>4</td>
</tr>
<tr>
<td>Lacks fruit</td>
<td>4</td>
</tr>
<tr>
<td>Lumpy</td>
<td>4</td>
</tr>
<tr>
<td>Shrunken</td>
<td>4</td>
</tr>
<tr>
<td>Surface growth</td>
<td>2</td>
</tr>
<tr>
<td>Wheyed-off (syneresis)</td>
<td>4</td>
</tr>
</tbody>
</table>

4. **LASSI**

Lassi, popular Indian soft drink is a product resulting from the growth of a selected culture usually lactic streptococci in heat treated whole or partially skimmed milk. At the desired ripeness 0.75-0.85% lactic acid, the coagulum is broken, admixed with sugar (or sugar syrup), and flavour and packaged in glass bottles or polyethylene bags. It is stored under refrigerated conditions and invariably served cold.

#### 4.1 Desirable characteristics of lassi

The colour of lassi should be pleasing, attractive and uniform. Normally, it varies from light yellow to whitish. In general, the good, clean, pleasant diacetyl flavour of a culture is desired in lassi. The natural flavour may be enhanced or enriched by the presence of milk fat.

The demands of trade vary as to the body of lassi. Some consumers prefer a heavy viscous body while others like a rather thin body. Consequently, no uniform standard can be fixed with regard to the body of lassi. However, a medium-bodied lassi pouring similar to a thin gravy, seems to be most appropriate. The texture should be homogenous showing no signs of wheying off or grains or curd particles.

#### 4.2 Score card for lassi

A score card based on 100 point scale is shown in Fig 1 and the guidelines in Table 3.
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Perfect Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavour</td>
<td>45</td>
</tr>
<tr>
<td>Body &amp; texture</td>
<td>30</td>
</tr>
<tr>
<td>Acidity</td>
<td>10</td>
</tr>
<tr>
<td>Colour &amp; appearance</td>
<td>10</td>
</tr>
<tr>
<td>Container &amp; closure</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*Fig. 1. Specimen sensory score card for lassi*

**Table 3. Suggested deductions from maximum score for different sensory attributes of lassi**

<table>
<thead>
<tr>
<th>Sensory attributes</th>
<th>Defect</th>
<th>Intensity of defect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Slight</td>
</tr>
<tr>
<td>Flavour (45)</td>
<td>High acid/green cheesy, bitter,</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>metallic</td>
<td>10</td>
</tr>
<tr>
<td>Body and Texture (30)</td>
<td>Curdy grainy, thin/thick body Ropy, wheying off</td>
<td>1</td>
</tr>
<tr>
<td>Acidity (10)</td>
<td>High acidity, Low acidity</td>
<td>3</td>
</tr>
<tr>
<td>Colour &amp; Appearance (10)</td>
<td>Uneven/unnatural colour</td>
<td>1</td>
</tr>
<tr>
<td>Container and closure (5)</td>
<td>Dirty improperly covered</td>
<td>1</td>
</tr>
</tbody>
</table>

5. SHRIKHAND

Shrikhand is an acid coagulated and sweetened milk product, which is a popular delicacy in states of Gujarat, Maharashtra and partly Karnataka. This indigenous dairy product is prepared by lactic coagulation of milk and expulsion of whey from the curd, followed by blending of sugar, flavour and spiced. The product has about 5% fat, 42% sugar and 60% TS. The shelf-life of the product is about 40 days at 8±1°C. A 100-point score card similar to the one shown in figure 2 carries a maximum score of 55, 30, 10 and 5 for flavour, body and texture, appearance and colour respectively. The sensory guide is given in Table 3 and 4.

**SELECTED REFERENCES**


IV. SENSORY ATTRIBUTES OF TRADITIONAL DAIRY PRODUCTS
1. INTRODUCTION

The sensory attributes of ghee are affected by many factors, such as quality of base material, extent of lactic acid fermentation, time and temperature of heating, rate of cooling, package type, filling conditions, presence of oxygen and contaminants such as iron and copper, exposure to sunlight and temperature, and duration of storage. These factors should be controlled to produce ghee of premium quality.

The quality of ghee is judged by the desirable flavour, texture and colour, and freedom from suspended serum residues. The consumer wants an assurance of purity, freshness and wholesomeness. These attributes are assigned relative weight in a descriptive mode by the overall assessment of quality. A perfect score of 60 for flavour, 25 for texture, 10 for colour and 5 for freedom from suspended impurities is recommended for the judging of ghee. The intensity of each defect is given on a weighted rating scale.

2. FLAVOUR

Aroma and taste constitute the flavour of ghee. A perfect ghee flavour is characterized by a multitude of sensory perceptions which are pleasant, enjoyable and lingering in the mouth. Consumers always resist any change in the flavour of ghee as this is one characteristic which predominantly determines acceptability. There are regional preferences for flavour in ghee. The preferred ghee flavours range from 'slightly curdy' to 'pronounced curdy', 'cooked' to 'caramelized' and, at times, slightly oxidized in some quarters of the population. The village-produced ghee is characterized by a curdy flavour which lingers in the mouth.

The quality and the amount of SNF present in the base material, as well as the intensity of heating separately and cumulatively, affect the flavour of ghee. Technologies have been developed using various alternate methods to produce ghee with both 'curdy' and 'cooked' type flavours.

The flavour of ghee is mainly contributed by the heat interaction products formed between the unfermented serum portion, comprising the native carbohydrate and protein system, and by metabolic products of the starter culture when ripened cream is used for ghee-making. The flavour components of ghee have been discussed in an earlier lecture. The 'curdy' flavour in ghee could be produced by mixing of desi ghee with dairy ghee in varying proportions, by the addition of lactic cultures to butter at heating, by incubating the molten butter with a lactic culture, or by the addition of 'lassi' powder at the time of heating.
'Cooked' flavour could be simulated by clarifying butter at temperatures of 115°C for 10 min, or 120°C for 5 min, or 125°C without any holding time.

3. TEXTURE

Granulation of ghee is an important criterion for its selection; a good grainy texture is very much appreciated by consumers, and such a ghee develops a lower degree of rancidity than ghee kept in the liquid state. Milk fat has the unique property of forming grains because it is made up of a wide variety of complex triglyceride mixtures with varying melting points. The texture of ghee will depend on the source of the fat (animal species), method of preparation, temperature of clarification, rate of cooling, amount of FFAs, rate of seeding, and storage temperature. The presence of FFAs markedly increases the grain size, but the quantity of grains is increased only to a limited extent. Seeding with grains of ghee at the rate of 2% by weight of ghee improves grain formation. The grain shape becomes needle-like, in contrast to the spherical shape obtained without seeding. The large number of fatty acid residues present in ghee result in a wide variety of crystallization patterns.

The maximum amount of solid fraction (about 74%) is obtained at 28°C in 20-24 hr from buffaloes' ghee, closely followed by cows' ghee (69.5%) and a distinct low in goats' ghee (30%). There can be significant differences in the melting curves of fat from the milk of buffaloes, cows and goats. The changes in the conditions of cooling can have a pronounced effect on ghee texture. If ghee is cooled rapidly, a larger number of very fine crystals will be formed, all consisting of mixture of high and low-melting fats, leading to smooth, grease-like character. Slow cooling of ghee from a temperature higher than the melting point will lead to formation of a few crystals with a high melting point. As cooling proceeds, more and more fat solidifies, forming a mass of large crystals suspended in liquid fat. Hard, greasy or waxy texture is not liked by consumers.

4. COLOUR

Buffaloes' ghee appears whitish in colour owing to the absence of carotene, which imparts a yellow colour to cows' ghee. In the village method of ghee-making, the development of greenish-yellow tinge in buffaloes' ghee is caused by the action of lactic acid bacteria. Ghee produced by the direct cream method has a darker colour compared to that prepared by the creamery butter process. Stratification results in a light colour. A more intense heating in the presence of a high SNF content will result in a darker colour, especially if the raw material has been fermented. Brown discoloration is a serious defect in ghee.

5. COMMON FLAVOUR DEFECTS OF GHEE

Although ghee has a better capacity to resist spoilage by elemental and microbial attack than any other milk product, it is common knowledge that, upon prolonged storage at ambient temperature, it undergoes oxidative changes. Reaction of oxygen with the 'unsaturated fat' is a major cause of spoilage. It gives rise to a typical, strong and disagreeable odour. Production of off-flavours accompanies the loss of nutritive value.

Auto-oxidation of ghee is aggravated by metallic contamination and sunlight. The 'acceleration' effect of light is dependent on its wave-length. The visible light accelerates the
Scisory attributes of ghee

decomposition of hydroperoxides. The effect of ultraviolet light on ghee is more pronounced than the impact of other rays. High-energy radiations, such as $\beta$ and $\gamma$ rays, exert a pronounced acceleration effect because they split hydroperoxides and also generate free radicals from molecules of unoxidized substrate.

The shelf-life of ghee is affected by the degree of unsaturation of fat, the temperature at which ghee is stored, the manner in which milk for ghee-making is handled, uncontrolled fermentation during curdling, uneven heating during manufacture, and sanitary conditions of the vessels used for the production and storage of ghee.

A number of synthetic antioxidants, such as gallates (ethyl, propyl, octyl), butylated hydroxy toluene (BHT), tertiary butyl-hydroquinone (TBHQ), ascorbic acid, d-tocopherol, phospholipids, and some natural antioxidants, namely curry leaves, betel leaves, soya bean powder, safflower and "amla" (*Phyllanthus amaricus*), can be added in small amounts (permitted legally in different countries) with a view to achieve either prevention or retardation of the oxidation of fat during storage. Traditional practice of ghee-making in India involves the use of certain plant leaves for antioxidative properties. Curry and betel leaves are two commonly used herbs which are rich in phenolic compounds, predominantly hydroxy chavicol. These leaves also contain ascorbic acid, which may act synergistically. Curry leaves and betel leaves also contain many amino acids which serve as antioxidants. Studies have proved that the practice of boiling betel and curry leaves with desi butter at the time of clarification helps to improve the flavour, colour and shelf life of ghee.

Other commonly encountered flavour defects in ghee are burnt, smoky, rancid and tallowy. The origin of these flavour defects will be discussed.

SELECTED REFERENCES


CHEMISTRY OF GHEE FLAVOUR
AND RELATED ASPECTS

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NDRI, Karnal- 132 001

1. INTRODUCTION

Work done during the last twenty-five years on ghee flavour has considerably enriched our basic and applied knowledge dealing with
- flavour profile of ghee
- flavour potential of ghee and ghee residues
- flavour simulation in butter oil and vanaspati (hydrogenated edible vegetable oils)
- renovation of rancid ghee
- role of dairy starter microorganisms

Wadhwa and Jain (1990) have extensively reviewed the chemistry of ghee flavour and variations in the level of flavour components as affected by various technological parameters. Employing the GC-MS technique, Wadolkar et al. (1996) have confined the identification of most of the ghee flavour components reported so far. Wadhwa and Jain (1991) have reviewed the simulation of ghee flavour in butter oil. Galhotra and Wadhwa (1993) while reviewing the chemistry of ghee-residue have highlighted the rich flavour potential of ghee residue and its possible utilisation. More recently, Wadhwa and Bindal (1995) have shown the utilisation of ghee-residue in flavouring vegetable fats and butter oil with simultaneous improvement in the keeping quality. Bindal and Wadhwa (1991) developed a simple and commercially viable method for the renovation of rancid ghee. Yadav and Srinivasan (1992) have reviewed the role of dairy starter bacteria in the enhancement of ghee flavour.

2. FLAVOUR PROFILE OF GHEE

2.1 Origin of flavour

Milk lipids are the source of a majority of the flavour compounds occuring in dairy products. These arise by various mechanisms as illustrated below:

\[
\text{HYDROLYSIS} \quad \text{FATTY ACID GLYC.} \quad \rightarrow \quad \text{FREE FATTY ACIDS (FFA)}
\]

\[
\beta - \text{KETO ACID GLYC.} \quad \text{HYDROLYSIS} \quad \text{DECARBOXYLATION} \quad \rightarrow \quad \text{ALKAN - 2 ONES.}
\]

\[
\delta - \text{HYDROXY ACID GLYC.} \quad \text{HYDROLYSIS} \quad \text{DECARBOXYLATION} \quad \rightarrow \quad \text{LACTONES.}
\]
UNSAT. FATTY ACID GLYC. AUTOXIDATION > ALDEHYDES, KETONES, ALCOHOLS

Proteins and lactose contribute to the flavour of milk products in the following manner:

PROTEIN => α-KETO ACIDS
(AMINO ACIDS)

LACTOSE, CITRATE FERMENTATION => DICARBONYLS

LACTOSE BROWNING => GLYOXAL, FURFURALS
CARAMELIZATION

2.2 Ghee flavour spectrum

Flavour of ghee analysed through gas liquid chromatography (GLC) has revealed a wide spectrum consisting of more than 100 flavour compounds as depicted below:

GHEE FLAVOUR SPECTRUM

<table>
<thead>
<tr>
<th>FREE FATTY ACIDS</th>
<th>CARBONYLS</th>
<th>LACTONES</th>
</tr>
</thead>
<tbody>
<tr>
<td>(16)</td>
<td>(49)</td>
<td>(44)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Polar</th>
<th>Polar</th>
<th>Delta</th>
<th>Gamma</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Diacetyl</td>
<td>C₆-C₁₀, C₁₃</td>
<td>C₆-C₁₆, C₁₉</td>
<td></td>
</tr>
<tr>
<td>- Methyl glyoxal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- α-Keto - glutaric acid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Furfural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Hydroxy methyl furfural</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Alkan-2-ones | Alkanals | Alk-2-Enals | Alka-2, 4-Dienals |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C₅-C₁₀, C₁₂</td>
<td>C₂-C₉</td>
<td>C₄-C₁₂</td>
<td>C₃-C₇-C₁₀-C₁₂, C₁₄</td>
</tr>
</tbody>
</table>

2.3 Technological Parameters

Flavour profile is affected quantitatively but not qualitatively by various technological parameters viz. method of ghee preparation, temperature of clarification and storage period (Table 1).
2.3.1. Free fatty acids (FFA)

The lower fatty acids, C6-C12, though present in low concentration (0.4-1 mg/g) accounting only 5-10% of total free fatty acids contribute significantly to ghee flavour. The concentration of both medium chain (C_{10-14}) and long chain (C_{15-18} and above) FFA is usually higher in cow than in buffalo ghee. Also the average total FFA level of cow ghee was higher than that of buffalo ghee. The average total FFA level of desi ghee is higher than the other two types of ghee (Table 1). The direct cream product is showing the lowest FFA concentration. This trend is in the tune with the flavour trend of three types of ghee.

2.3.2 Carbonyls

'Head space' and 'volatile' carbonyl content of fresh desi cow ghee is higher than that of buffalo ghee, whereas the 'Total' carbonyl content of fresh desi buffalo ghee is higher than that of cow ghee. On storage for 100 days at 37°C, off flavour has been found in ghee samples with about 3 fold rise in head-space and 2 fold rise in 'volatile' and 'total carbonyls' both. After 200 days storage, pronounced off flavour developed with about 8, 4 and 3 fold increase in head space volatile and total carbonyls respectively.

2.3.3 Lactones

The lactone level in buffalo ghee has been found to be higher than that in cow ghee. It was the highest in DC ghee followed by CB and lowest in desi ghee. Thus this trend is opposite to the increasing flavour trend from DC to CB to desi. Apparently, lactones are only one component of ghee flavour and the others viz, free fatty acids and carbonyls are probably more dominant. The lactone level in butter (12 ppm) increased 1.9, 2.4, 2.8 and 3.0 fold on clarifying at 110°, 120°, 140° and 180°C (Table 1). The near doubling of the lactone level on clarification of butter at 110-120°C contributes to a pleasing flavour of the product. Lactone levels in ghee showed a significant rise on storage.

3. FLAVOUR POTENTIAL OF GHEE - RESIDUE

Ghee-residue is the by product of ghee manufacturing industry. Ghee-residue is rich in fat, proteins and minerals and is a natural antioxidant. Recent studies have revealed that apart from its nutritional and antioxidant properties, ghee residue is also a rich and natural source of flavour compounds viz. FFA, carbonyls and lactones. The level of FFA, carbonyls and lactones in ghee-residue are respectively 11, 10 and 132 times those in ghee as shown below:

Concentrations of major flavour compounds in ghee and ghee residue

<table>
<thead>
<tr>
<th></th>
<th>FFA (µm/g)</th>
<th>Carbonyls (µm/g)</th>
<th>Lactones (µm/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghee</td>
<td>(53.6)</td>
<td>(43.7)</td>
<td>(30.3)</td>
</tr>
<tr>
<td>Ghee-residue</td>
<td>(627.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghee</td>
<td>(4.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ghee-residue</td>
<td>(3992.9)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1. Flavour potential of ghee as affected by various technological parameters

<table>
<thead>
<tr>
<th>Flavour compounds</th>
<th>Species</th>
<th>Method of preparation</th>
<th>Temp. of clarification (°C)</th>
<th>Storage (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cow ghee</td>
<td>Buffalo ghee</td>
<td>DC</td>
<td>CB</td>
</tr>
<tr>
<td>FFA (mg/g)</td>
<td>5.0-12.3</td>
<td>5.8-7.6</td>
<td>5.8-7.3</td>
<td>6.0-7.3</td>
</tr>
<tr>
<td></td>
<td>0.035 (H)</td>
<td>0.027 (H)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carbonyls</td>
<td>0.33 (V)</td>
<td>0.26 (V)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>(umoles/g)</td>
<td>7.20 T</td>
<td>8.64 (T)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lactones (ppm)</td>
<td>30.3</td>
<td>35.4</td>
<td>41</td>
<td>30.3</td>
</tr>
</tbody>
</table>

H - Head space carbonyls
V - Volatile carbonyls
T - Total carbonyls
DC - Direct cream
CB - Creamery butter
4. ROLE OF DAIRY STARTER MICROORGANISMS IN GHEE FLAVOUR

The various biotechnological parameters have been optimized and a product (direct cream, ghee) comparable in flavour to desi ghee obtained. In the optimised process, cream (40% fat), steamed and cooled is ripened with a lactic culture DRC- at 3% level of inoculum and 30°C for 18 hr, and clarified at 115°C/ 5 min. In a further modification, the ripening period of cream could be reduced by 6 hr by using a starter concentrate (viable count, 68 x 10^10 cells/ml) at 1% level.

5. CONCLUSION

The chemistry of ghee flavour has been extensively studied. Free fatty acids, carbonyls and lactones are the major groups of compounds contributing to ghee flavour, the first two apparently playing a more important role than the last. Further, various flavour simulation studies suggest possible innovations in making ghee via butter oil. Simulation of ghee flavour in butter oil and Vanaspati through ghee residue (by product) is recommended as the simplest and most economical method producing flavoured fats with enhanced shelf life. Rancid ghee can be renovated through a simple technology followed by flavour simulation.

SELECTED REFERENCES


1. INTRODUCTION

Ghee, the most important Indian Dairy product, owes its unique position among edible fats mainly due to its attractive flavour. It is the most expensive and considered highly prized dietary fat in India. Then why is the Indian consumer willing to pay such a high price for ghee? This is mainly due to its pleasing natural flavours, which cannot be duplicated by any other fat or any other food article.

Now what makes dairy flavours different from other food flavours? As discussed by an earlier speaker, ghee flavour is a balanced mixture of several volatile and non-volatile components present as such or their precursors in minute concentrations, and most prominent among these are: free fatty acids, lactones, carbonyls, alcohols, aromatics, sulphur compounds, benzene compounds etc.

There is abundant literature regarding the isolation, purification and characterization of ghee flavour but I shall mainly confine myself to the research work conducted at this Institute, with a special reference to the role of gas liquid chromatography (GLC).

2. FREE FATTY ACIDS (FFA)

The presence of FFA in ghee at desired level (5.9-12.3 mg/g fat in cow ghee and 5.8 to 7.6 mg/g in buffalo ghee) is known to play an important role in ghee flavour. It is rather difficult to get an insight of the true picture of FFA in ghee due to fairly solubility in water of lower chain FFA (C₆, C₇) which are most important towards contribution of flavour. Earlier methods (Singhal and Jain, 1973; Ramamurthy and Naryanan, 1974) suffer from one major drawback that these lower chain FFA escaped detection during analysis either during to their removal in aqueous phase or remained with the adsorbent due to their insolubility in organic solvents.

Consequently a lower estimate of FFA was quoted in these research papers. The method reported by Wulff et al. (1980) and involves extraction and isolation of FFA as their potassium salts and the injection of these salts into GLC. This method required helium gas saturated with formic acid vapour as carrier gas for the separation of lower chain FFA. Such conditions are normally not available here. Sharma and Bindal (1987) developed a GLC method for the estimation of FFA in ghee without their prior isolation from Ghee and this method gave the true estimate of FFA present in ghee. They prepared the methyl esters
of FFA with glycerides of ghee in the presence of Methyl urea which formed a complex with glycerides and did not react with FFA. The free FFA when treated with BF₃ formed methyl ester and methyl urea-glyceride complex remained inert. The methyl esters of FFA thus formed were analysed in GLC in routine manner using 10% DEGS.

Table 1. Average composition of FFA (mg/g) present in cow and buffalo ghee samples prepared by different methods

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>COW GHEE</th>
<th></th>
<th></th>
<th>BUFFALO GHEE</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct Cream</td>
<td>Creanery butter</td>
<td>'Desi'</td>
<td>Direct Cream</td>
<td>Creanery butter</td>
<td>'Desi'</td>
</tr>
<tr>
<td>4:0</td>
<td>-</td>
<td>-</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>6:0</td>
<td>-</td>
<td>-</td>
<td>0.11</td>
<td>-</td>
<td>-</td>
<td>0.24</td>
</tr>
<tr>
<td>8:0</td>
<td>0.04</td>
<td>0.11</td>
<td>0.2</td>
<td>-</td>
<td>-</td>
<td>0.27</td>
</tr>
<tr>
<td>10:0</td>
<td>0.11</td>
<td>0.08</td>
<td>0.23</td>
<td>0.14</td>
<td>0.27</td>
<td>0.32</td>
</tr>
<tr>
<td>10:1</td>
<td>-</td>
<td>-</td>
<td>0.06</td>
<td>-</td>
<td>-</td>
<td>0.01</td>
</tr>
<tr>
<td>12:0</td>
<td>0.26</td>
<td>0.37</td>
<td>0.59</td>
<td>0.31</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>12:1</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>14:0</td>
<td>0.74</td>
<td>0.91</td>
<td>1.33</td>
<td>1</td>
<td>1.27</td>
<td>1.12</td>
</tr>
<tr>
<td>14:1</td>
<td>0.03</td>
<td>0.03</td>
<td>0.1</td>
<td>0.1</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>14:2</td>
<td>0.03</td>
<td>-</td>
<td>0.04</td>
<td>0.01</td>
<td>-</td>
<td>0.04</td>
</tr>
<tr>
<td>16:0</td>
<td>2.82</td>
<td>2.16</td>
<td>4.14</td>
<td>2.39</td>
<td>2.92</td>
<td>2.87</td>
</tr>
<tr>
<td>16:1</td>
<td>0.03</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>16:2</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>18:0</td>
<td>0.73</td>
<td>0.24</td>
<td>0.52</td>
<td>0.16</td>
<td>0.21</td>
<td>0.24</td>
</tr>
<tr>
<td>18:1</td>
<td>2.31</td>
<td>1.74</td>
<td>4.27</td>
<td>1.25</td>
<td>1.3</td>
<td>1.17</td>
</tr>
<tr>
<td>18:2</td>
<td>0.07</td>
<td>0.2</td>
<td>0.37</td>
<td>0.25</td>
<td>0.19</td>
<td>0.35</td>
</tr>
<tr>
<td>Unidentified</td>
<td>0.13</td>
<td>0.07</td>
<td>0.15</td>
<td>0.05</td>
<td>0.18</td>
<td>0.19</td>
</tr>
<tr>
<td>Total</td>
<td>7.32</td>
<td>5.99</td>
<td>12.29</td>
<td>5.83</td>
<td>7.25</td>
<td>7.58</td>
</tr>
</tbody>
</table>

The data (Table 1) revealed that short chain fatty acids (C4, C6, C8) neither escaped esterification nor were washed away during purification of methyl ester.

3. CARBONYLS

Several workers have reported that carbonyls, both volatile as well as non volatile, contribute significantly towards ghee flavour. Volatile carbonyls constitute only 5% of total carbonyls (Gaba and Jain, 1974). The non-volatile carbonyls (95% of total) are believed to augment or modify the effect of volatile flavour components.

Gaba and Jain (1974) made extensive studies regarding volatile carbonyls in ghee. The carbonyls were trapped into 2, 4 DNPS to form hydrozones. Monocarbonyls were
GLC analysis of ghee flavour

separated from Dicarbonyls over Magnesia-celite (2:1) plates using nitromethane chloroform (1:3). Monocarbonyls, the principal flavouring compounds were further resolved into classes over similar TLC plates using methanol and hexane (1.25:100) and the classes were estimated spectrophotometrically.

The monocarbonyl-DNP mixture of each class was dissolved in laevulenic acid (0.12 ml) at 60°C and resolved by GLC (Carbowax 20m, 25% on Diatoport W, 60-80 mesh; column temperature, 125°C. On the basis of these studies, the authors identified as many as 34 carbonyls in fresh ghee.

4. LACTONES

Lactones are the most potent flavouring compounds, the optimum threshold values of which fall in the ppm range for the desired flavour.

Methods like distillation (steam, vacuum or cold finger molecular) or column chromatography (silicic acid adsorption or acidic Alumina celite) have been reported for the isolation of lactones from fat based products. Out of these cold finger molecular distillation is most effective. Other methods are time consuming and also involve the use of heat and thus measures only free lactones. However, most of work on lactonic flavour in India has been done using steam distillation, the reasons being the unavailability of facilities like vacuum degassing and molecular distillation in most of the laboratories.

Vacuum degassing at low pressure (10^-4 mm) and temperature (80°C) is ideal for mild product like butter oil. Molecular distillation at 40°C was employed for the isolation of lactones from Cheddar cheese.

Wadhwa et al. (1984a, 1984b, 1989) improved upon earlier methods of lactones isolation and introduced a celite digitonin alumina column chromatographic method. Digitonin was introduced to eliminate cholesterol which otherwise interfered in analyses. The acetoneitrile eluant from column recorded about 90% lactonic fraction. This fraction showed 44 peaks when analysed by GLC using column of 10% DEGS coated on 100-120 mesh Diatomite C (AW). The column temperature was maintained at 160°C for 40 min and then increased at a rate of 15°C min upto 195°C.

Very recently Wadodkar et al. (1996) isolated the total volatiles from ghee heated at 120°C for 30 min under vacuum degassing at -15°C and the volatiles thus obtained were fractionated by GLC (15% DEGS coated on chromosorb - W (H.P.) 80-100 mesh) equipped with FID using temperature programming (for 80°C for 20 min. followed by temp rise at the rate of 5°C/min. upto 150°C for 30 min and finally 170°C for 40 min). The total volatiles yielded 42 peaks under these conditions. These volatiles were also separated over capillary columns of GLC (30 to 60 meters x 0.25 mm) of DB1 and DBWAX and identified by mass spectrometer. Sixty eight components comprising carbonyls, free fatty acids, alcohols, lactones and hydrocarbons were isolated and most of these were identified. However, the harsh heat treatment of ghee (120°C for 30 min) is expected to increase the flavour potential considerably and such increase may not provide the true picture of normal ghee flavour and possibly heat flavour may be encountered.
REFERENCES


SENSORY ATTRIBUTES OF SOME CONCENTRATED AND COAGULATED TRADITIONAL DAIRY PRODUCTS

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Dairy Technology Division
NDRI, Karnal-132 001

1. INTRODUCTION

The wide range of indigenous Indian dairy products can be classified into seven major kinds based on the different processing technologies used in their manufacture. These are:
(1) Heat concentrated/desicated products
(2) Heat-and-acid coagulated products
(3) Fermented products
(4) Fat-rich products
(5) Frozen products
(6) Cereal-milk mixes
(7) Milk sweets and confections or "Novelties" prepared by combining one or more indigenous milk products with non-dairy ingredients.

The flavour, texture, colour and consistency of each class of products are distinctly different. The scientific literature of sensory analysis of indigenous products comprises methodological studies on taste testing (assessment of reaction to products in a test situation), investigations of sensory processes (the way one responds to physical stimuli) and statistical experimental designs.

2. SENSORY PROFILES OF TRADITIONAL PRODUCTS

Consumers use a stretchable "rubber bag" of terms to describe each product. The list of terms used for traditional products may not be found in a general list. Qualitative and quantitative differences exist that would describe different varieties of products, distinctly different from each other. Researchers have gone beyond hedonic measurements to intensity scaling for each term. Quantitative descriptive analysis and spectrum. Following the development of "flavour profile", researchers have now "texture profile" methodologies using instrumental methods of analysis. There are many descriptors that can be used for product evaluation. Colour science helps us with a model showing how the seven colours (VIBGYOR) of the rainbow are expressed as combinations of three primary, familiar (red, blue and yellow) colours representing a combination of wavelengths. Beside the subjective visual techniques, instrumental methods of colour measurements are finding increasing application in dairy products.

3. SENSORY PROPERTIES OF KHOA

The complex physico-chemical properties greatly contribute to sensory attributes. Since many of the indigenous dairy products are manufactured on small scales, wide variations are observed in the sensory properties as a result of various kinds of milk used, methods of preparation, manner in which the products are packaged, stored and transported, and the regional preferences. Varietal differences such as obtainable in three types of khoa, viz. Findi, Dhap and Danedar are significant. Many of the sensory attributes are desired to be developed in the three varieties because of different end usages.
G.S. Rajorhia

The three varieties of khoa possess different flavour and textural properties. The major flavour compounds isolated from khoa are of lipid and protein origin and have been identified as carbonyls, sulphhydrals and disulphides. Browning intermediates formed during storage by interaction of lactose and milk proteins cause reduction in flavour scores.

4. SENSORY ATTRIBUTES OF CHHANA AND RASOGOLLA

Chhana possess pleasant curdy flavour, soft and smooth texture, and a pasty consistency. It should be free from coarseness. Mechanical pressing of the coagulum is avoided to save chhana from the becoming compact, hard and brittle. The pasty consistency allow the formation of spongy rasogolla and smooth sandesh. The colour of chhana depends on the type of milk used; it is yellowish if made from cow’s milk and creamy-whitish from buffalo’s milk. There should be no signs of free fat on the surface of the product.

Good quality rasogolla have a uniform whitish colour. Round balls should not get deformed when squeezed. The surface should be rough and moist. The flavour will be like chhana along with sweet taste. The innermost portion should have the same flavour as the outer one. The texture of rasogolla will depend on its variety. It should not have any scum or fat on the surface.

5. FROZEN PRODUCTS

Kulfi is an important Indian frozen product prepared from a mixture of preconcentrated milk, sugar, flavours and nuts. Unlike ice-cream, kulfi possesses intense cooked flavour, fine texture, very little overrun and high melting resistance. The presence of natural flavours like cardamom, saffron, etc. makes the product highly acceptable. The quality of kulfi is determined by its raw material, composition, flavouring, colouring, method of processing and storage period. The effect of new technology developed for industrial scale on sensory properties will be discussed.

6. OTHER PRODUCTS

6.1 Misti dahi, a fermented product

Heating of milk in the presence of cane-sugar is continued to reduce the volume of milk, to develop cooked flavour and to induce browning (hence, lal dahi). In some cases, sugar caramel, jaggery and artificial colours are added to impart brown colour. A firm, gel-like coagulum is formed. Diacetyl is the predominant flavour component but micro quantities of acetoin, acetic acid, carbonyls and alcohols are also present. Off-flavours in misti-dahi can be traced to poor quality raw milk, use of faulty cultures, high incubation temperature and contaminated packages.

6.2 Basundi

It is a sweetened concentrated milk product served chilled as a dessert. It has condensed milk-like appearance with flakes, pleasant condensed milk-like flavour and cooked taste.

The sensory attributes of other Bengal-type sweets, khoa-based sweets, cereal milk preparations, and other confections and novelties will also be discussed.
V. SENSORY ATTRIBUTES OF MILK & VEGETABLE PROTEIN PRODUCTS
1. INTRODUCTION

Edible casein, caseinates as salts of sodium, calcium, potassium, magnesium etc., whey protein concentrates (30-80% protein), coprecipitates and protein hydrolysates are the major milk protein products. They are used in bakery products, meat products, confectionery items, beverages and in a wide variety of formulated foods and animal feed products. They are also increasingly being used in dietary preparations and pharmaceutical and medical applications.

Most of the applications of milk protein products require them to be neutral or bland in taste and smell, colourless and free from extraneous matter. However, a lot more attention has been given on the flavour aspects of these products in the literature than on appearance, as flavour is considered the most important sensory quality.

2. STANDARDS FOR SENSORY ATTRIBUTES OF MILK PROTEIN PRODUCTS

Among the different protein products, only edible casein has been assigned national and international standards, particularly with respect to sensory qualities. As per BIS standards (IS:1167-1965), casein shall be nearly white or pale cream in colour and shall have no undesirable odour or any foreign matter; it shall be free from any added colour. The size of the particles shall be such that 100% by weight of casein shall pass through 500-micron IS sieve.

As per international standards (FIL - IDF 45:1969), flavour and odour of acid precipitated edible casein must be neutral, free from offensive flavours, taste and odours such as sour, cheese or metallic off flavours. Colour of the product should be white to pale cream. If ground, it should be free from lumps that do not break up under slight pressure. The maximum sediment (scorched particles) allowed is 22.5 mg in 25 g spray dried and 32.5 mg in 10 g roller dried product. The casein should not contain any foreign matter such as particles of wood, metal, hairs or fragments of insects. European Community standards (No. L237/29) are more or less similar to international standards in respect of sensory attributes.

3. FLAVOUR OF MILK PROTEIN PRODUCTS

Freedom from flavour defects is very important in many of the applications of milk proteins as food ingredients. In industrial practice, fresh casein, caseinates, coprecipitates and
V.K. Gupta

whey proteins are usually bland in flavour. On storage, milk proteins tend to develop unpleasant flavours variously described as gluey, stale, burnt-feather or musty. Good progress has been made in research into the origins of the flavours. Ramshaw & Dunstone (1969a, b) found a large range of volatile components in the steam distillate of gluey casein. Their findings suggested that the flavour resulted from a mixture of compounds with some synergistic effect from α-aminoacetophenone, a compound of low volatility possibly arising from breakdown of tryptophan. The type of compounds which seemed significant in the flavour spectrum and their experiments on manufacture of casein and coprecipitates indicated that non-enzymatic browning reactions were involved in the off flavour development. It appeared that reducing substances produced by this reaction subsequently degraded to flavour components. Ramshaw & Dunstone (1970) reported trials in which dispersions of milk proteins were heated to encourage this degradation so that the volatile flavour components could be removed during spray drying. By using browning inhibitors (1970b), they also obtained improved flavour stability of low-Calcium-precipitate, where the longer heating time for the milk can initiate browning reactions.

Industry has sought to obtain the best flavoured product by such techniques as reducing the lactose content by thorough washing and avoiding excessive heating at any stage of manufacture so as to minimise browning reactions. The manufacture of caseinate from fresh wet curd and minimizing its storage time before use also helps in obtaining the best flavour. However, on the basis of comparing ferricyanide reducing values with flavour of low lactose casein, Walker (1970) concluded that the browning reaction did not contribute significantly to development of musty off-flavour.

Sharma & Hansen (1970) linked development of gluey flavour on heating casein with breaking of ester phosphate bonds. Ramshaw & Leary (1970) found that UV treatment of casein gave unpleasant odours as well as gluey flavour. The treatment appeared to accelerate degradation of tryptophan but not the browning reaction. Table 1 gives the threshold concentration of gluey flavour in treated and untreated casein.

The flavour of coprecipitates tends to follow a similar pattern to that of the caseins, high calcium coprecipitates being more stable than low calcium (acid) coprecipitates and fresh-curd soluble coprecipitates being better than those reconstituted from dry, granular, insoluble coprecipitates (Southward and Goldman, 1978) The coprecipitates, as a class, may also tend to exhibit 'cooked flavour' overtones as a result of the high heat treatment given to the milk during their manufacture (Southward, 1985). Particle size of granular caseins and coprecipitates also appears to affect their flavour; finely ground product tend to exhibit stronger off-flavours than coarser fractions.

Whey protein concentrates develop a typically stale off-flavour during storage due to a set of complex, inter-related chemical reactions which include lipid oxidation and Maillard browning. There is no information in the literature on the volatile organic compounds responsible for off-flavour in whey protein concentrates (Morr and Ha, 1991). Important possible off-flavours in milk protein products are listed in Fig. 1.
### Milk protein products

Table 1. Threshold concentration of gluey flavour in treated and untreated casein

<table>
<thead>
<tr>
<th>Materials and/or treatment</th>
<th>Threshold concentration (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gluey casein</td>
<td>0.3</td>
<td>Control</td>
</tr>
<tr>
<td>Gluey sodium caseinate</td>
<td>0.3</td>
<td>Control</td>
</tr>
<tr>
<td>Fresh freeze-dried casein or sodium caseinate</td>
<td>&gt;3.0</td>
<td>Control</td>
</tr>
<tr>
<td>Vacuum-treated casein or caseinate</td>
<td>0.3</td>
<td>Flavour not removed</td>
</tr>
<tr>
<td>Steam-distilled sodium caseinate</td>
<td>&gt;1.0</td>
<td>Flavour partially removed</td>
</tr>
<tr>
<td>Distillate from sodium caseinate</td>
<td>1.0</td>
<td>Distillate gluey</td>
</tr>
<tr>
<td>Freeze-dried sodium caseinate (1, 5, 10%)</td>
<td>0.3</td>
<td>Flavour not removed</td>
</tr>
<tr>
<td>Reprecipitated casein</td>
<td>1.0</td>
<td>Flavour partially removed</td>
</tr>
<tr>
<td>Filtrate from reprecipitation</td>
<td>1.0</td>
<td>Filtrate gluey</td>
</tr>
<tr>
<td>Washed casein</td>
<td>&gt;1.0</td>
<td>Flavour partially removed</td>
</tr>
<tr>
<td>Wash water</td>
<td>1.0</td>
<td>Wash water gluey</td>
</tr>
<tr>
<td>Activated carbon-treated casein</td>
<td>&gt;3.0</td>
<td>Flavour removed</td>
</tr>
<tr>
<td>Sephadex G 25-treated casein</td>
<td>&gt;3.0</td>
<td>Flavour removed</td>
</tr>
</tbody>
</table>

*Concentration at which gluey flavour was first detectable*

**FLAVOUR EVALUATION OF MILK PROTEIN PRODUCTS**

Evaluator _____________________ Date _____________________ Product _____________________

Desirable Flavour : Bland Flavour

**Suggested off-flavours :**

<table>
<thead>
<tr>
<th>Serious</th>
<th>Non-serious</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astringent</td>
<td>Acidic</td>
</tr>
<tr>
<td>Bitter</td>
<td>Caramel</td>
</tr>
<tr>
<td>Fussery</td>
<td>Cereal</td>
</tr>
<tr>
<td>Burnt (cooked)</td>
<td>Milky</td>
</tr>
<tr>
<td>Card board</td>
<td>Nutty</td>
</tr>
<tr>
<td>Fishy</td>
<td>Sweet</td>
</tr>
<tr>
<td>Metallic</td>
<td></td>
</tr>
<tr>
<td>Mouldy</td>
<td></td>
</tr>
<tr>
<td>Gluey</td>
<td></td>
</tr>
<tr>
<td>Putrid</td>
<td></td>
</tr>
</tbody>
</table>

**Guide for overall Score (0-10)**

<table>
<thead>
<tr>
<th>Off Flavour intensity</th>
<th>Serious off-flavour</th>
<th>Non-serious off-flavour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent (Abs)</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Threshold (Thr)</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>Slight (Sl)</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Moderate (Mod)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Strong (Str)</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: Type of off flavour may be described by using abbreviated terms

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Serious off-flavour</th>
<th>Non-serious off-flavour</th>
<th>Over all Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Off Flavour</td>
<td>Intensity</td>
<td>Off Flavour</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Time of Evaluation _____________________ AM/PM _____________________ Signature of the Evaluator

Fig. 1. Score-card for flavour evaluation of milk protein products
4. METHODOLOGY FOR THE EVALUATION OF THE FLAVOUR OF MILK PROTEIN PRODUCTS

A method was developed at New Zealand Dairy Research Institute that has been widely used to assess the flavour characteristics of protein products. Sodium or calcium caseinate is dissolved in water at 60°C, using mechanical stirring, to produce 10% (w/v) caseinate solutions. Acid casein is treated similarly except that sodium hydroxide solution is carefully added to dissolve the casein to produce solutions of sodium caseinate at pH 6.7. Rennet casein is dissolved with sodium tripolyphosphate (5% w/w of casein) to produce solutions of pH 7-8. Because the viscosity of a rennet casein solution is greater than that of a sodium caseinate solution, the concentration of the rennet casein is usually reduced to 8% (w/v) but, for calcium caseinate, which is less viscous than sodium caseinate, the concentration is not increased correspondingly.

The coded samples to be tasted (all of one type, such as acid casein, or sodium caseinates, etc.) are presented in random order to each taster at a temperature of about 40°C. Marked and coded 'good' and 'bad' control samples are included. Water and dry bread are used between each sample to remove dry lingering impression from the mouth.

A typical flavour evaluation score sheet, as used for all casein products, is shown in Fig. 1. To assist the taster in describing off-flavours, the score sheet includes a list of suggested serious and non-serious off-flavour descriptions. The taster is asked to give an overall score (scale 0-8, where 8 = excellent, 6 = good, 3 = poor, 0 = extremely objectionable) to each sample based on the type and intensity of off-flavour.

A guide for relating the type and intensity of off-flavour to the overall score is also given; serious off-flavours absent, 8; threshold, 7; slight, 5 etc. Mean values and standard deviations for overall score and intensity of off-flavour are computed in the usual way. For the purpose of summarizing the information, off-flavour intensity is converted into a score: 1 = absent, 2 = threshold, 3 = slight, 4 = moderate, 5 = strong.

The use of a large panel of trained tasters and the inclusion of reference points for both ends of the scoring range (control samples) provide a reasonably reliable estimation of the flavour quality of any casein sample. Mean panel scores at the bottom (0-3) and top (6-8) of the range are normally more reliable than those in the middle (4-5) where standard deviations of greater than 1 are not uncommon. In general, however, the method has been a valuable tool for placing casein products into various flavour categories prior to selecting them for use in foods.

5. APPEARANCE OF MILK-PROTEIN PRODUCTS

Granular casein should be of uniform particle size prescribed in standards, or of commercially desired mesh sizes like 30, 60 and 90. Desirable colour of casein is white to pale cream; however, buffalo milk casein has natural greenish tinge. Browning and other discolorations are the colour defects.
Milk protein products

Caseinates, whey protein concentrates and coprecipitate powders should possess almost similar colour as the casein. Whey protein concentrates, coprecipitates and sodium, potassium and ammonium caseinates make translucent, viscous, straw-coloured solutions, while calcium caseinate forms micelles in water, producing an intensely white, opaque, 'milky' solution of relatively low viscosity.

6. PROTEIN HYDROLYSATES

The production of protein hydrolysates provides an opportunity for the dietary management of persons suffering from digestive disorders as a result of pancreatic malfunction, pre- and post operative abdominal surgical patients, patient on geriatric and convalescent feeding, and others who for various reasons are not able to ingest a normal diet. However, enzymatic hydrolysis of protein has frequently been shown to give bitter taste to digests due to liberation of bitter tasting peptides or amino acids. In aqueous solution, hydrophilic or polar groups of casein are on the outer surface and hydrophobic groups are packed inside the molecule. Enzymatic digestion exposes the peptide moieties which contain large amount of hydrophobic amino acids which on contact with the taste buds give a sensation of bitterness.

Khanna (1991) used a 9-point Hedonic scale for comparison of sensory quality of casein hydrolysates adjusted to 10% T.S. concentration. For sensory evaluation of bitterness of casein hydrolysates, Khanna (1991) used 4-point scale, where 1 = extremely bitter, 2 = distinctly bitter, 3 = slightly bitter, and 4 = not bitter. Saline water (2%) was provided to the judges for rinsing their mouth before tasting each sample. The judges noticed the following sensory characteristics in different samples of casein hydrolysates:

i) Flavour: Stale, foul, acidic, salty, sour and fruity.
ii) Colour: Dull white, yellowish, sparkling clear, yellowish brown and red.
iii) Sediment: No sediment.

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SENSORY PROPERTIES OF VEGETABLE PROTEIN PRODUCTS AS INGREDIENTS FOR DAIRY ANALOGUES

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1. INTRODUCTION

India is the second largest populated country in the world, and as such it has been a great challenge for us to meet the requirement for food. Though the green and white revolutions were great boons to increase the food supply, quality protein supply is still inadequate especially for the vegetarian populace of our country. If we compare the diet of an average Indian with that of a person in the developed nations, we find that the average Indian diet contain only 45 g protein as against the requirement of 55 g for an adult. This protein being of inferior quality, if corrected for quality, by taking into account the essential amino acids, the actual protein intake works out to be only 34 g. This has resulted in protein calorie malnutrition, which is widely prevalent amongst the lower income groups of the populace of this country.

Milk is considered to be a common food - a good source of high quality protein. However, it is not within the reach of all who need it because of its high cost and low purchasing power of a majority of the population. Looking into these facts and figures, it becomes imperative to make best use of available local food sources such as cereals, oil seeds, dairy-by-products etc, for the manufacture of low-cost nutritious protein supplement foods.

Amongst all vegetable proteins, soybean protein assumes the most prominent position as protein supplement not only because it is high in protein (35-45%) and lipids (18-22%) but also because of the presence of adequate amounts of all the essential amino acids except sulfur amino acids, that are required for human body. The potential of soybean cultivation as an economic crop, under the agro-climatic conditions prevalent in the country, has been well established; and the area under soybean cultivation is steadily increasing, particularly in Madhya Pradesh, Uttar Pradesh and Punjab.

While making reference to any dairy analogue or fabricated food, soybean automatically stands out as a raw material, owing to its nutritional and functional virtues. Further soybean milk analogue and products made from it, would also be valuable for people intolerant to cow's milk. However, there are several problems associated with soybean which stem from, among other factors, its sensory properties.
2. SENSORY PROPERTIES OF SOY PRODUCTS

Volatile components are responsible for highly characteristic odours associated with soybeans and various soy products and are derived enzymatically or thermally from non-volatile precursors in soy protein material e.g. protein, peptides, amino acids, carbohydrates, lipids and vitamins. Some of these aromas are acceptable, but in many cases they are undesirable and even offensive. Raw beans and raw flours have a predominant odour which is characteristically described as green, grassy and beany (Kahlbrenn et al. 1971) Moser et al. (1967) showed that 80% of their sensory panel could detect these qualities of raw full flat soylflour, even when diluted to the extent of 1:750 with a nonodour wheat flour. In general, the odours of concentrates and isolates are often more bland than those of flours.

3. FACTORS LIMITING THE USE OF WHOLE SOYBEANS

Soybean unless properly processed is of little value in human nutrition. The raw soybean protein has very low PER. This is because of the presence of some anti-nutritional factors such as trypsin inhibitors, hemagglutinin, etc. Apart from anti-nutritional factors, the flatulence factors such as oligosaccharides and off-flavour producing factors, such as lipoxygenase affect the use of soybean as food.

One of the simplest methods for converting soybean into a high protein food is to extract or grind the beans with water to produce a beverage known as soymilk, which has been a staple food in the orient for many centuries. But the product has a distinct flavour, described as Painty, or beany that is generally unacceptable to most outside people of East Asia. It has now been established that the painty flavour is quickly generated by the endogenous enzyme, lipoxygenase, whenever soybean are ground in the presence of sufficient moisture.

Many studies using sophisticated chemical techniques for analysis, such as gas liquid chromatography and mass spectroscopy, have shown that the great number of compounds produced by the action of lipoxygenase result from the formation of very unstable intermediates with subsequent double bond migration and splitting of the native fatty acids of soybean molecules. The low molecular weight volatiles isolated, particularly the ketones and aldehydes such as pentanal, hexanal and ethyl vinyl ketone, contribute to the off-flavour, but no one component completely characterizes the painty, beany, bitter off-flavour. Though no thresholds for the off-flavour has been established, as little as one part in one billion of the reaction product can be detected by flavour evaluation. Therefore, once formed, it is difficult and expensive to remove sufficient reaction product to impart a bland taste to the resulting beverage.

4. PROCESSING OF SOYBEAN

Numerous procedures have been developed to improve the Oriental process with regard to flavour and/or protein recovery. These procedures include hot water grinding, acid grinding, alkali soaking, addition of antioxidants, extrusion cooking, extensive grinding followed by high pressure homogenization protein isolation etc. However, the problems
such as less acceptable flavour, grainy mouth-feel, and the instability of colloidal suspension could not be entirely eliminated.

4.1 The Illinois Process

These problems have been largely solved with a process developed by the Food Processing Laboratory in the Department of Food Science, University Illinois USA. Blanching or cooking dry whole soybeans or subdivided dry soybean cotyledons, thus inactivating the lipoxygenase enzymes before it has an opportunity to act. The resulting beverage is claimed not only to have a smooth mouth-feel and be completely free of painty flavour but also has the versatility to be used in various dairy analogues.

Preparation of the Illinois process soymilk includes soaking and then blanching the whole soybeans in 0.5% sodium bicarbonate, grinding with water in hammermill, heating the slurry to 93° C (200°F), homogenizing, nutralizing, diluting, adding sugar and flavour, pasteurizing, and re-homogenizing. Lipoxygenase enzyme inactivation by blanching prior to grinding the soaked beans was found to completely prevent formation of painty flavour and to result in a bland flavoured product. Trypsin inhibitors are also inactivated by blanching. Non-protein fractions mainly such as oligosaccharides which are reportedly associated with the flatus problem are largely leached out in soak and blanch water. A sufficient degree of tenderization of soybean tissue during the soak and blanch treatments yields a good mouth feel and colloidal stability.

4.2 Dairy and non-dairy analogues developed at NDRI, using soy-solids

Based on the Illinois process with some modifications, certain dairy and non-dairy analogues e.g. frozen, high-fat, cultured, and desiccated, confectionary products, weaning foods, biscuits etc. have been developed at this Institute. Considering soybean strange to the Indian palate, it was found necessary to incorporate some of the milk solids in one or the other form to make the product more acceptable. Sensory panel and consumer studies have shown that the sensory acceptability of most of these products is very satisfactory.

5. SOY ISOLATES AND CONCENTRATES

The present commercial production of soy-protein-isolates and concentrates is geared to the removal of the solubles in the starting material to produce a bland end product. However, large quantities of both edible and industrial grades of soy protein isolates are currently produced in the USA. There exists little published information with respect to the specification of design, equipment and operation of the plants. The large scale commercial know-how is limited to a few industrial organizations and several patents have been taken on the isolation of soy protein in its native states as well as with the desirable flavour and functional characteristics for various uses.

6. OTHER VEGETABLE PROTEINS AS MILK SNF SUBSTITUTES

The use of other vegetable proteins as substitute for MSNF has been reported in literature, but these are of little commercial significance because of their limitation regarding
quality, quantity and economy of production. The use of groundnut protein isolate has been tried to develop an acceptable non-dairy icecream at CFTRI Mysore (Ramanna, 1975). Lawhons et al. (1980) also reported that the ground-nut isolate could replace MSNF at 80% level without affecting texture and 60% without affecting the overall acceptability.

Use of glandless cotton seed flour, deglanded cotton seed flour (Simmons et al., 1980) or cotton seed protein isolate (Lawhon, et al., 1980) has been tried successfully to replace MSNF.

It has also been reported in the literature that edible powders from green leaves (Anon., 1974) could be used to replace MSNF ice-cream.

7. CONCLUSION

A highly characteristic and often undesirable flavour associated with soy protein material largely explains the slower than expected progress over recent years in the development of high protein food based on soya. Apart from the inherent flavour of the beans, different flavours are produced on processing and on storage. However, processing of soybean by the Illinois process, addition of synthetic flavours, and incorporation of milk solids have resulted in products quite comparable to that of milk based products.

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VI. GENERAL ASPECTS OF SENSORY EVALUATION
1. INTRODUCTION

Packaging contains, protects and preserves the product, and informs the user. It provides two more functions - those of selling and convenience. Efficient packaging is a necessity for every kind of food. It is an essential link between the food producer and the consumer, and unless performed correctly the standing of the product suffers and customer goodwill is lost.

Foods are packed and stored for maintaining the product’s nutritional, hygienic and sensory qualities. There are many ways in which the flavour of a food may be affected by the packaging material and the conditions of storage. The flavour of the food may show change quantitatively by loss of its total aroma intensity through, for example, the permeability of the packaging films or qualitatively by loss of some of its aroma constituent. It may also acquire foreign aroma from direct contact with the packaging material or from the ingress of environmental odour of the storage container or room. When there is a quantitative loss, the product tends to become flat; when there is foreign aroma acquired by the food, it is termed ‘tainting’ of the food, particularly if the acquired aroma is offensive or unacceptable.

Food product packages must be both functional and aesthetic, well designed food containers should simultaneously satisfy both criteria. The desirability for attaining an attractive container that has lasting consumer appeal is obvious. In the interest of quality assurance, a functional package should protect the food product against all known applicable modes of quality deterioration, including sensory properties. In view of this, it is very essential to understand the new packaging for high sensory quality processed foods.

2. PACKAGING IN A CHANGING FOOD INDUSTRY

One of the most noticeable evidences of change in the processed food industry today involves the new forms of packaging that have begun to appear on store shelves. The universe of these new structures is characterized by terms such as retortable, dual ovenable, microwavable, aseptic, hi-barrier, co-extruded, etc. To the consumer they offer convenience and quality attributes in step with modern lifestyle expectations and demographic factors. Consequently, the food processor must meet the challenges of these new technologies to prosper, and whoever does this well, may determine who remains viable in today’s increasingly competitive marketplace.
Not so long ago packaging choices for processed foods were relatively few. Retorted and hot filled products were available in cans and glass containers of varying sizes. Frozen items were available in boil-in-bag type pouches and foil trays. These packages were proven performers and played an important role in building and maintaining the confidence of the public in the safety and sensory quality of processed food products.

Shelf stable (retorted) items are beginning to compete. They offer extremely rapid heating in the microwave oven and surprisingly high quality, because their low profile tray type packaging reduces the amount of thermal processing required to achieve commercial sterility. Packaging of this type must have sufficient oxygen barrier for a one to two year shelf life at ambient temperature, must be compatible with the processing environment of a retort and must maintain seal integrity during processing and distribution. Coextruded barrier containers utilizing ethylene vinyl alcohol or saran as the barrier material are popular, but newer barrier materials are also under development.

Aseptic packaging is a technology wherein the product and package are separately sterilized, and the product is then filled into the package and the leakage sealed in a sterile environment. The product is commercially sterile (meaning that any pathogenic or other spoilage microorganisms have been destroyed) and shelf stable (does not require refrigeration or freezing). Economic saving are realized in many cases by the use of lighter weight packaging materials such as polymer/foil/paper laminations or coextruded container constructions. Many aseptic packaging systems are based on form fill seal technologies that eliminate the need to ship preformed containers to the processor.

Convenience in the aseptic product category is offered by products such as snack puddings and dips in open thermoformed containers, and the single serving juices in brik style containers with the punch through attached straw; Instant snacks and lunch box items for busy parents to serve. Higher sensory quality product may result from the use of ultra high temperature (UHT) processes for aseptic products, because these usually result in less heat induced loss of product quality versus processes that heat the product in its container. Aseptic packaging is now spreading from predominantly fruit juices into other product categories such as soups, gravies, baby food, tomato sauce, dairy drinks and yoghurt.

3. PACKAGE REQUIREMENT

It is evident that packaging is playing an enhanced role in bringing high sensory quality products to the consumer that are in keeping with today's marketplace demands. Packaging plays a crucial role in delivering a safe and wholesome product to the consumer. The major packaging challenges facing food processors today is to assure that package related factors that affect the microbiological and chemical integrity of food products are understood and controlled in the production, distribution and handling of products whether they are frozen, refrigerated or shelf stable (aseptic or retorted).

Frozen products rely on freezing to retard microbial growth and chemical degradation. The package is not generally called upon to form a micro or gas barrier around the product. Its principal function is to physically protect the product under the stressful conditions of frozen distribution and sale. Also, if the product is intended to be cooked in its retail container, the package must not chemically adulterate the product through the
migrating of toxic or off flavour components from the package during the cooking process. The latter applies for any food product type that is processed or cooked in its retail container.

Extended shelf life refrigerated products utilize refrigerated distribution, usually in combination with other factors (such as control of pH, water activity, package gas composition, use of chemical preservative and processing) to retard microbial growth and chemical degradation, and thus achieve high sensory quality and an extended shelf life. Such products can be marketed as premium products. A successful package for this type of product must be capable of maintaining the controlled or modified atmospheric composition selected for the product, particularly if such control is crucial to the microbiological safety of the product.

Shelf stable products are rendered commercially sterile by heating the product to achieve the destruction of pathogenic microorganisms either:

(i) within a sealed container, or (ii) separate from the container followed by aseptic packaging of the product. Sterilization of the container may be accomplished by treatment of the container with heat, a chemical sterilant (e.g., hydrogen peroxide), ionizing radiation or combinations of these. The package for any shelf stable product must constitute a microbiological barrier to the exterior of the container. Maintenance of the product’s commercial sterility depends upon this.

If the product’s commercial sterility is compromised through a breach in the package’s integrity, spoilage of public health significance could result depending on the type of microbial contamination that occurs, the nature of the product and the environment within the container. Because of the potential risks involved, the issue of package integrity for shelf stable food products is probably the most intensely scrutinized and cautiously approached challenge associated with new packaging technology in the food industry.

4. CHALLENGES TO BE MET

From a food processor’s perspective following factors must be understood and controlled to assure the safety and wholesomeness of processed food products.

4.1 Seal integrity

Seal integrity is critical to assuring the safety of shelf stable products maintaining high sensory quality. Many new plastic container types utilize heat to seal a lid to a container body. Heat sealed containers may employ a peelable or fusion (non-peelable) seal. The later, which generally results in a greater seal strength, can be utilized on packages such as retortable pouches where the package is not opened by peeling at the seal area.

No lidding/sealing concept is right for every packaging application. Factors that should be considered in choosing a packaging system include the type of product, its intended processing, the type of secondary packaging to be used, and the rigours of the distribution system. A thorough approach to assessing a package’s seal performance would include performing simulated abuse testing and trial distribution shipments on commercial units (i.e., palletized shipping units) followed by an examination of the seal and the entire package.
Processors should also have an ongoing quality control program for seal evaluation of finished containers prior to commercial shipment.

4.2 Influence of the Retort Environment

The use of flexible and semi-rigid container types in retort applications require an understanding of retort induced effects that may effect process adequacy and package integrity. For example, containers build up internal pressure in a retort to an extent that depends upon factors such as the type of product, pre-processing treatments (blanching), the amount of entrapped gases in the product and the temperature within the container. If internal container pressure distorts the shape of the container during processing, the adequacy of the thermal process could be affected. In addition, excess internal container pressure could place undue stress on the heat seal. In retort systems, over pressure, provided by air, steam or steam/air mixtures is applied to prevent container deformation, and represents a critical process factor.

4.3 Aseptic System

In a commercial aseptic packaging operation for low acid foods, it is of critical importance that the operator control system parameters that affect package sterility and integrity. Aseptic packaging equipment must be thoroughly tested before commercial operation to assess the system's design and the performance of sterilization, filling and sealing operations.

5. CONCLUSION

Conquering the challenges of the new packaging technologies that affect of food sensory and chemical quality, and safety are undoubtedly major pursuits of the food industry. For selected food products, the application of modified atmospheric packaging, the evolution of packaging and products tailored specifically for use with microwave oven need emphasis. The food processors must know the relationship of the package to the product, and utilize their resources in cooperation with suppliers and with each other, to stay on top of the challenges that they face.

SELECTED REFERENCES


1. INTRODUCTION

With the increasing awareness amongst the people in the recent years regarding the type and quality of the food they consume, it is important that the industry provide the consumers such products which are wholesome, distinctive in quality, value and convenience. Sensory evaluation, therefore, plays a vital role in the dairy and food industry, as it provides the information which may be utilized for setting standards, quality control, assessment of process variation, cost reduction, product improvement, new product development, analysis of market, and correlating sensory with chemical, physical and instrumental measurements. From the consumer's point of view also, it is one of the primary characteristics on which the value and sale of the product is decided. Hence, this aspect becomes more important to the economic success of a product.

2. METHODS FOR DETERMINING THE PRODUCT QUALITY

There are two basic approaches in determining the quality of the product (Gould, 1976).

2.1 Subjective methods

Subjective methods are based on the opinion of the investigators. It is usually a physiological reaction which is a result of past training, experience of the individual, influence of personal preference, and powers of perception. They are subjective because the individual is required to give his opinion as to qualitative and quantitative value of the characteristic or characteristics under study. These methods usually involve the various sense organs, and so they may be referred to as sensory methods. Example of sense perceptions are flavour, odour, colour, or touch.

Food and dairy products can be analysed for chemical and microbiological composition, vitamin content, enzymic activity, colour and physical properties, but these determinations do not measure the eating quality of the product (Nelson and Trout, 1964). The "eating quality" of a product includes all those sensations such as feel, taste and smell which the consumer experiences when the product is taken into mouth. Although the essentials that go to make up the "eating quality" of food products cannot be measured by ordinary chemical and physical means, they can be determined by sensory evaluation to a high degree of accuracy by competent judges.
2.2 Objective Methods

Objective methods are based on observations from which the attitudes of the investigators are entirely excluded. They are based on recognized standard scientific tests and are applicable to any sample of the product without regard to its previous history or ultimate use. They represent the modern idea in quality control and new product development because the human element has been excluded. They can be divided into physical, chemical and microscopic methods.

The relative advantages of objective measurement are: They may be applicable at higher concentrations than subjective ones without the danger of fatigue mechanism interfering. The objective procedure can be used repeatedly, although with subjective methods the relative discrimination of the subject can be improved by training. Consequently, in practice, whenever a physical or chemical test can be run to obtain an objective measure of food quality with high degree of accuracy, the objective method is preferred (Pomeranz and Meloan, 1987).

The disadvantage of instrumental procedures is that the instrument may "repeat" readings when changes in the material may invalidate the correlation with subjective judgement. This simply means that continuous rechecking against the subjective reaction is necessary. However, important limitations of some instruments are that they respond over a period of minutes and measure only one attribute, whereas the human senses respond within seconds and measure the composite "mouthfeel" (Amerine et al, 1965). However, many instruments can be arranged to operate automatically or semi automatically, and thus much time is saved. Although the limitations of objective tests must be recognized, the large cost, the large amount of work involved and the uncertainty in evaluating foods precisely and meaningfully by sensory tests are also well established. Methods which isolate or differentiate a single quality factor are most likely to be useful, but several procedures may be needed to express overall quality adequately. The ideal objective methods should be rapid, accurate and precise.

As the final criterion of quality is human evaluation, the value of objective tests must be assessed for efficacy by their correlations with sensory tests. This correlation should normally be higher for better understanding of the nature of the physical and chemical parameters involved. A correlation of 0.90, or more, is desirable albeit in some cases pertinent inferences can be drawn with correlations as low as 0.80. For predicting responses in production, however, very high correlations are necessary.

Eventhough sophisticated and high sensitive measuring instruments such as gas chromatographs, mass spectrometers, nuclear magnetic resonance spectrometers, pulse nuclear magnetic resonance spectrometer, IR and UV spectrophotometers etc. are now available, the importance of sensory analysis has grown rather than diminished. Most instrumental analysis have come to realise that only through the coordination of instrumental and sensory analysis an optimal information be obtained. Even at the limit of instrumental sensitivity, e.g. where no signal appears, our "biological detector" (our senses) may still perceive an odour, taste etc. Additionally, the instruments will only analyse single components, whereas our senses give us a total impression of aroma, taste, temperature and tactile components (Jellinek, 1985).
3. NEW PRODUCT DEVELOPMENT

In the formulation of new foods, or modification of the existing products while maintaining the desirable sensory characteristics, e.g. assurance of minimum sensory standards in nutrient fortified foods for domestic as well as for export purposes, and the development of substitutes for consumers on special diets such as low-calorie, low-sodium, low-cholesterol, or lactose-free regimens, sensory evaluation plays a pivotal role.

3.1 What sensory tests can do in product development

Sensory evaluation techniques have been used to assess the progress of the product development in the food industry for many years. Many consumers purchase a product on the basis of the sensory experience which it delivers (sweetness, softness, melt, etc.). Food technologists in general, and sensory analysts in particular, recognize the need to focus attention on measuring the perception of these characteristics and/or the reaction to them.

Sensory tests can provide helpful input in many areas (Erhardt, 1978, Baker et al., 1994) which are delineated as under:

3.1.1 Confirm intentional/unintentional changes in product/ingredient formulation

They can provide data to confirm that changes have been made in the direction indicated by the consumer tests. They can also be used to determine whether unintentional changes have occurred in the product during reformulation. The evaluation provides assurance that the desired changes are perceptible in an objective test situation.

Sensory evaluation can also be used to determine whether additions of a certain ingredient affects the flavour of a product, e.g. whether vitamin fortification results in the perception of "off" or vitamin-like notes. A discrimination test will indicate how confident we can be that flavour differences are not perceptible between the control and fortified samples. Panelists can evaluate competitive product to identify changes and improvements and to compare new products to their competition to determine similarities and differences. Replacing an ingredient because of cost or availability without changing the product characteristics is difficult. In-house sensory panels are ideally suited for evaluations of this kind. Discrimination tests using sensitive panelists will determine which samples match the control and which are perceptibly different. If panelists do not detect a difference and if the test methods and procedures are sound, the requester can be comfortable accepting the substitute ingredient.

3.1.2 Determine if optimization has been achieved

In new product development, sensory tests provide the developer with correcting information and guidelines for product improvement. Tests can be used to determine which characteristics of the latest formulation do or do not meet the product mix. Formulations can be also evaluated by sensory panels to determine whether optimization of product quality has been achieved. Effects of usage conditions, e.g. use of microwave oven on product
characteristics can be described and measured, and results can be compared to previous test results to document improvement and progress.

3.1.3 Observe changes during processing/storage

Scaling-up products from bench-top to pilot plant and from pilot plant to large scale production will often result in product changes. Sensory panels can be used to detect and identify the differences between the desired product and production. With an accurate description of the changes perceived in the production sample, the cause can sometimes be more readily identified and corrected.

Aging effects can be studied through sensory evaluation. Tests can be specifically designed to identify and monitor product changes due to storage. Such stability evaluations are an important phase of product development, and trained panelists and a sound test design are terra incognita in providing valid data for shelf-life determination.

3.1.4 Identify areas for improvement

The effects of various packaging materials on product characteristics can be evaluated using in-house panels. Test samples can be evaluated at certain check points over time to test for possible changes in the product. Changes in the processing of product may alter the product characteristics, and sensory tests can be used to determine whether differences between the control product and the product produced by new process are perceptible.

3.1.5 Monitor product quality

Tests can be designed to monitor the quality of the manufactured product and to determine whether products slowly drift away from the intended quality over a period of time. Products obtained through commercial production can be evaluated against the sensory specifications established during the R&D phase. Identification and description of product differences between plant shifts and runs is helpful in spotting problem areas and maintaining product quality.

3.1.6 Substantiate advertising claims

Sensory tests can also be used to provide data to substantiate advertising claims and statements. If the product is billed as "better tasting", "shiner", "brighter", or "more comfortable", panelists can pinpoint products characteristics and their responses can be measured.

3.2 Benefits in new product development

First of all, sensory evaluation takes the guess work out of new product development. It represents the first opportunity the developer has for feedback on his product. In this early development stage, there are essentially two paths that can be followed (Blair, 1978). One is to develop an option, test it, modify it as indicated, test again, modify it on the basis of new data, and so on, until the "optimum" product is developed.
The alternative is to run some experiments, using several product options in which we systematically alter variables. This is where we have the opportunity to fully understand the impact of various attributes on overall acceptability, as well as the interaction of these attributes. We may, away from having panelists, tell us if a product is too sweet, optimum, or not sweet enough, since it is frequently difficult for people to form such a judgement. With the application of experimental design principles, we can judge the acceptability of a product attribute by comparing ratings for products in which that attribute has been varied.

The sensory evaluation process permits you to form data-based points of view about your product. It lets us know where we were and where we are now. It gives us a first approximation of overall acceptability, how the product rates on various dimensions, and which dimensions appear to interact most with overall acceptance.

It is not uncommon in the new product development process to match, move closely to, or differentiate your product from some other product. This "other" product could be some commercially available product or a home-made product. Sensory evaluation approaches permit us to "fingerprint" the alternative product and then learn how our prototype does or does not match this alternative product and then learn how our prototype does or does not match this alternative (Blair, 1978).

Additionally, and importantly, we start to build a vocabulary about the product; we start to learn how to think and talk about product attributes. This area of vocabulary is important and also quite complicated. A real opportunity exists in developing a linkage from the language that emerges from sensory work to that used by consumers.

Another important benefit of sensory evaluation tests with the development of a database. One benefit of such a database is being able to better evaluate the data for the current product by comparing them with normative data. However, the database should include only data for successful established products, not data for products tested early in the developmental stages or products that were developed and later failed in the market, unless the failure was for non-product related reasons.

4. CONCLUSION

A competent sensory analyst will develop and utilize valid procedures and methods to evaluate product characteristics. The basic principles should be applied whenever sensory characteristics are evaluated in the developer's laboratory or in any decision-making situation involving product perceptions. Although concept, price, brand, advertising, convenience, and other factors are important to consumer acceptance, the inherent sensory properties are the major factor in determining the product's overall acceptability. Since sensory input can improve the probability that a product will be successful, the expertise of the sensory analyst should be utilized whenever possible to assure timely and objective feedback to research and development. Though flavor, color and texture measurements can become technically difficult or sophisticated, the bottom-line, however, is "Does the consumer like the product?" The human response, therefore, can not be ignored.
REFERENCES


1. INTRODUCTION

In today's competitive market, consumer is the most important individual who obtains and uses a commodity. Therefore the sensory perception and preference of consumer population is most important for any food manufacturing organisation. The organisation involved in new product development and preservation of traditional and ethnic food products has to conduct consumer population surveys to obtain realistic and homogenous information on their products.

The present discussion relates to consumer studies, the factors influencing consumer acceptance and preference, and conducting of consumer surveys. The consumer panel is essentially a group of individuals representative of a specific population whose behaviour is to be measured through survey. It is distinct from a laboratory panel, which is not necessarily the representative of any specific consumer population. Depending on the consumer panel and objective of the survey, the methodological approach may vary.

2. CURRENT STATUS

Consumer studies/surveys are being conducted regularly on different products by R&D organizations attached with food manufacturing factories (Schoner, 1991; Lawless and Classen, 1993; Lawless et al. 1995; Adams et al. 1995). Consumer testing of any product is always done with the help of carefully selected randomized group of consumer population which is not trained in sensory evaluation and has no experience of such judging.

German Agricultural Association conducts consumer studies on different dairy products, like cheese, butter, UHT milk of different milk plants (available in the market) every year to select most liked samples. The manufacturer of 'liked' samples are remarked with gold, silver and bronze medals (Heiss, 1990). European countries have successfully used these techniques of involving consumer to know his/her expectation and preference and then matching it with the sensory characteristics and attributes of a given product (Benz, 1991).

In India, we are highly dependent on laboratory panels and are not involving consumers at large in product development. This is true for the dairy industry in particular and food industry in general. This may be due to non-competitive food/dairy market.
3. FACTORS INFLUENCING CONSUMERS' ACCEPTANCE AND PREFERENCE

For conducting a successful consumer survey one must know the important factors which may influence ones survey results and conclusions.

Many complex factors combine to influence the consumers' acceptance and selection of any food (Table 1). Therefore, it becomes very difficult to ascertain the role of sensory attributes of the product in getting any food selected by consumers. These all complete factors interact and influence the consumers' decisions. Sensory attribute is only one of them. The aim of the study should not only be sensory evaluation but there should be a total approach to know why consumer has accepted or rejected the product. A good product packed nicely may not be accepted by consumer because of its high price tag. In some surveys, hypothetical prices have been assigned to samples and consumers asked to make selections. It was obvious, the samples with lowest cost with relatively good sensory attributes were selected and excellent samples with high prices were not found in their selection lists. The conclusion one could draw is that excellent samples with a very high price are likely to be rejected for a given target population. Price is an important limitation of the freedom, which the consumer selects.

Table 1. Consumer and product related factors affecting acceptance and preference

<table>
<thead>
<tr>
<th>Attributes of the food product</th>
<th>Attributes of the consumer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Availability</td>
<td>1. Regional preferences</td>
</tr>
<tr>
<td>2. Utility</td>
<td>2. Nationality, race</td>
</tr>
<tr>
<td>3. Convenience</td>
<td>3. Age and sex</td>
</tr>
<tr>
<td>4. Price</td>
<td>4. Religion</td>
</tr>
<tr>
<td>5. Uniformity and dependability</td>
<td>5. Education, socio-economics</td>
</tr>
<tr>
<td>7. Safety and nutritional value</td>
<td>a. Symbolism of food</td>
</tr>
<tr>
<td>8. Sensory properties</td>
<td>b. Advertising</td>
</tr>
<tr>
<td>a. Appearance</td>
<td>7. Physiological motivation</td>
</tr>
<tr>
<td>b. Aroma and taste</td>
<td>a. Thirst</td>
</tr>
<tr>
<td>c. Texture, consistency</td>
<td>b. Hunger</td>
</tr>
<tr>
<td>d. Temperature</td>
<td>c. Deficiencies</td>
</tr>
<tr>
<td>e. Pain</td>
<td>d. Pathological conditions</td>
</tr>
</tbody>
</table>

3.1 Regional preferences

Some regional food preferences exist for specific foods such as coffee (variation in roasts and blends), ghee (variation in flavour preference:curdy in the west and cooked in the south) and shrikhand (liked in western region).

The results or sample survey for sensory attributes may differ from one regions to another region due to their age old perceptions and preference. However due to organized
country wide production of products like ghee and free movement of products, the regional preferences seem to be diminishing to some extent.

3.2 Age and sex

The age of the consumer has been reported to influence preferences for some food products. In a study, filled yoghurt (with milk fat as control) prepared with maize, sunflower, groundnut or olive oil was given to three age groups (<20, 20-30 and >30 years). All the 3 groups rated control yoghurt highest and sunflower yoghurt lowest, but only the 20-30 year age group detected any appreciable difference between the other 3 types of yoghurt. (Adams, et al 1995).

Difference in personality, sensory acuity and likes and dislikes are usually more pronounced between people of the same sex than between the two sexes as groups. There are, however, group differences between the sexes which can be effectively used in planning and conducting market survey campaigns. However, in view of incomplete and inconclusive information, it is difficult to predict preference behaviour of specific age groups, or of males versus females, for most food products.

3.3. Other factors

Interest, motivation, discrimination, intelligence, and many other attributes of consumers undoubtedly influence responses to food.

Individual variation in sensory acuity influences responses at consumer level as well as in the laboratory. The interrelationship of physiological nutritional and psychological factors must be taken into account for conducting extensive surveys of olfactory and taste abilities of the potential consumers.

4. METHODOLOGY

4.1 Objective of the consumer survey

There is always a target of conducting particular consumer market survey. This objective essentially governs the selection of methodology, population, age group and sex, and type of questionnaire to be used. The target objective has its typical attributes and problems which are to be taken into consideration before conducting the actual survey. The objective of a survey may be:

i) Determination of market potential.
ii) Introduction of new products.
iii) Quality assessment and control of existing products.
iv) Establishment of specific factors of importance to the consumer.
v) Impact of advertising campaigns and educational programmes.
vi) Effect of group feeding.
vii) Testing of methods and statistical procedures.
4.2 Different approaches

To collect the response of consumer there could be three possible approaches (i) Historical, based on past records of sales and turnover, (ii) Observational based on data collected by trained person(s) on the behaviour of consumers in the market and (iii) through well worked and targeted questionnaire response.

4.2.1. Historical method

To understand the present market and estimate future market events the investigator must consult statistics of food distribution, sales records, and product turnover rates. These records are analysed and extrapolated to know future trends. Unknown reasons for drop in sales has to be predicted through observational and questionnaire response method in a market situation. Statistical records of the market provide information to the investigator about the area, region and population be considered for conducting consumer preference studies.

4.2.2. Observational method

In this method a trained person(s) is employed to observe group behaviour of consumers and can gather quantitative and qualitative data on food habits and ways of selection. Hidden observers can watch consumers in super markets to determine whether purchases are planned or impulsive to establish what displays and packaging appeals to them to determine whether certain food items are selected more often by men than by women. Merchandisers may be interested in knowing the role of background music, product location, lighting or other physical or psychological factors responsible for consumer behaviour. Advertisers and producers are interested in how the consumer appraises the product - does he/she smell it, squeeze it, weigh it, read the label, study instruction, or compare it with other on the shelf. Expert observers may take help of video-cameras for close observation and hidden microphones to enhance their efficiency. The value of observation method can be enhanced if same consumers are interviewed through questionnaire to find out the difference between 'activity' and 'response'.

4.3 Questionnaires

Carefully worded questionnaires are frequently used to obtain consumer reaction on a multitude of topics related to selection and use of commodities. The questionnaire may range from one short question to several hundred inquiries about past, present and future behaviour. The effectiveness of this method depends on the questionnaire, and the degree of co-operative spirit elicited from the consumer as well as, the type of approach employed. The method may be : i) in-depth interview, ii) word association iii) sentence completion iv) projective questioning vi) role playing vii) recorded group discussion and viii) pre-test questionnaire.

With the questionnaire method the most common approaches are : telephone, mail, personal interview, and public test. All these approaches have advantages and disadvantages. However, personal interview is most reliable way of obtaining information on food
Consumer acceptance studies

preferences and it has an advantage of collecting consumers observational data concomitantly. The consumer may be approached in interview after serving the samples to obtain their opinions. At the same time they are also observed for their behaviour in buying the product to establish a correlation of degree of liking with buying behaviour.

4.3.1 Types of questionnaires

Opinion questionnaire

When opinions of consumers are sought, the following are the type questions:

i) True-false response
ii) Yes-no response
iii) One-word answer
iv) Multiple choice
v) Essay type
   a. Why do you_______?
   b. What do you think of_______?
   c. What would you do if_______?

4.3.2 Selection of questionnaire

The selection of a questionnaire used to judge select experimental food depends on the number of treatments, sensory intensity of the food commodity, and the information desired. Following is a list of examples of presentation method suitable for consumer survey purpose:

I. Single-sample presentation
   a) Acceptable or unacceptable
   b) Degree of liking
   c) Description (with or without suggested terminology)
   d) Numerical scoring

II. Paired-sample presentation
    Identified-product paired comparison in which sample of known quality is compared against sample of unestablished quality.
    i) General preference
    ii) Degree of preference
    iii) Difference testing
    iv) Quality scoring or scaling devices
    v) Blind paired comparison, in which the quality of neither sample has been established previously.

III. Three sample presentation
    a) Triangle test
    b) Ranking
    c) Quality scoring or numerical scaling
    d) Descriptive terms
    e) Duo-trio

IV. More than three samples
    a) Ranking
    b) Scoring or scaling
    c) Degree of liking

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5. LIMITATIONS OF CONSUMER SURVEY

Consumer surveys are expensive, time consuming and subject to numerous uncontrollable variables. Although most surveys yield valuable information, investigators experience many problems and should recognize the limitation of their method.

The response of consumers, as individuals, or as a group, can easily be underestimated or overestimated. The following consumer characteristics are encountered in many surveys:

- Inability to remember, to generalize, or to identify motives.
- Inability to describe likes, dislikes and attitudes.
- Inability to weigh the numerous alternatives.
- Unawareness of what influenced their behaviour.
- Awareness of more factors than the impact of influence warrants.
- Desire to please the interrogator.
- Desire for social status, prestige, and 'keeping up with the Joneses'.

However, by correct wording of questionnaire most of the above traits can be avoided or diminished. Collaborative studies between food technologists, economists, psychologist and statisticians must be conducted for making consumer behaviour more predictable.

SELECTED REFERENCES


VII. RHEOLOGY OF DAIRY & FOOD PRODUCTS
1. INTRODUCTION

Rheology has been defined as a branch of physics concerned with the deformation and flow of matter. It deals primarily with the relationship between the forces and time on one hand and deformation and flow on the other hand. Thus rheological measurements provide information in physical terms regarding the behavior of food when a force acts on it. Such information is important to the food processor from two distinct standpoints: (a) Process control and product handling, and (b) evaluation of texture as an attribute of food quality.

Texture is the sensory perception of mainly mechanical and to a lesser extent, auditory and tactile properties of food. Thus rheological measurements are aimed at depicting the major, mechanical component of texture. The present discussion pertains to rheological classification of foods including relevant terminology.

2. RHEOLOGY-BASED FOOD CLASSES

The difficulty in classifying foods depending on their rheological behavior can be visualized from the fact that it is not always possible to differentiate precisely between liquid and solid foods i.e. it is not easy to pinpoint where in the consistency range the transition from liquid to solid takes place. Some products have properties of both liquids and solids. In spite of this difficulty, it is convenient to classify the foods rheologically, by assigning them to one of the two groups viz., fluid and semi-solid food and solid foods as done below.

3. FLUID AND SEMI-SOLID FOODS

Fluid flows can be categorized as Newtonian flow and non-Newtonian flow.

3.1 Newtonian fluids

These fluids more exhibit a pure viscous flow i.e. the product begins to flow with the slightest force and the rate of flow is proportional to the magnitude of force applied. The plot of stress, or shear stress (tangential force per unit), versus the rate of shear strain (or angular strain) also known as the shear rate or velocity gradient (defined as the rate of variation of the angle formed between two segments which were originally perpendicular) is a straight line passing through the origin (Fig. 1). The shear stress divided by the corresponding shear rate yields Newtonian Viscosity (η) also termed as dynamic viscosity, absolute viscosity or coefficient of viscosity. It is expressed in Pa.s, or poise or centipoise.
Milk, clear fruit juices, egg products (unfrozen whole egg at 21°C, stabilized egg white, yolk), plain/sucrose solutions, most types of honey, and corn syrups are examples of Newtonian fluids.

![Diagram](image)

**Fig. 1. Stress-shear rate relationships in different rheological classes of fluids**

### 3.2 Non-Newtonian foods

A large number of foods do not show a linear relationship between stress and shear rate. The flow properties of such non-Newtonian fluids are influenced by the shear rate at a constant temperature. Since the viscosity varies with the shear rate, fluids are characterized by apparent viscosity ($\eta_\gamma$) at a specified shear rate. Non-Newtonian flows may be time independent or time-dependent.

#### 3.2.1 Time - independent flow of non-Newtonian foods

The fluid foods whose viscosity is not influenced by the shearing time at a constant shear rate show two distinct patterns of stress - shear rate relationship: shear thinning and shear-thickening.

##### 3.2.1.1 Shear-thinning or pseudoplastic fluids

A pseudoplastic fluid shows the stress to increase at a decreasing rate as the shear rate increases i.e. the apparent viscosity decreases with increasing rate of shear. The stress ($\tau$)-shear rate ($\dot{\gamma}$) curve is convex toward the stress axis. The shear-thinning behaviour of a fluid or semi-solid food is expressed by the power law model or de Waele's model:

$$\tau = K \dot{\gamma}^n$$

where $K =$ consistency constant (Pa.s$^n$)

$n =$ flow behaviour index (has a positive value between zero and unity)
Rheological classification

Protein concentrates, skim milk concentrate, milk ultrafiltration retentates concentrated fruit juices such as unpectinized apple juice (50-65° Brix), orange juice (60-65° Brix) etc., melted chocolates, thawed frozen egg, fruit and vegetable purees and gum solutions are the examples of shear-thinning products.

3.1.1.2 Shear-thickening or dilatant fluids: Certain types of honey and cooked starch paste are examples of fluid foods which exhibit an increasing apparent viscosity as the shear rate increases. The stress shear rate curve is concave toward the stress axis (Fig. 1) and the value of n in the power law model (Eq. 1) is negative.

3.2.2 Time-dependent fluid flows

Certain non-Newtonian fluids show a time-dependent stress-shear rate relationship which can be one of the two types as discussed below.

3.2.2.1 Thixotropy: When at a constant shear rate, the stress decreases over a period of time due to structure breakdown until eventually it reaches a steady value, the product is said to be thixotropic. If, instead of keeping the shear rate constant, it is first increased and then immediately decreased at the same rate, the upward stress-shear rate curve does not coincide with the downward curve, but a hysteresis loop is obtained (Fig. 1). Aged condensed milk, cream and ice cream mix, egg white etc. reveal thixotropy.

3.2.2.2 Rheopectic fluids: These fluids exhibit an increase in shear stress with time of shear at a given shear rate. However, no rheopectic foods have been reported so far.

3.2.3 Plastic fluid flow

Some non-Newtonian foods show a yield stress (τₙ) that must be overcome by the applied stress for flow to occur. Such yielding foods may show an ideal (or Bingham) plastic flow characterized by a linear increase in stress (in excess of the yield stress) with the increasing shear rate (Fig. 1) which can be described by the Bingham plastic model:

\[ \tau - \tau_0 = \eta' \gamma \]  \hspace{1cm} (2)

where \( \eta' \) = plastic or Bingham viscosity.

In many foods, however, the yield behaviour may be accompanied by shear-thinning, which may be given by the Herschel-Bulkley model:

\[ \tau - \tau_{0H} = K_H \gamma^{nH} \]  \hspace{1cm} (3)

where \( \tau_{0H} \) is yield stress, and

\( K_H \) and \( n_H \) are parameters similar to the power law parameters, \( K \) and \( n \).

Plastic foods may also follow time-dependent stress-shear rate behaviour i.e., like pseudoplastic foods, they may be thixotropic in nature.
4. SOLID FOODS

Solid foods are generally characterized in terms of stress-strain relationship. The stress may be of tensile, compressive, tangential (shear) or torsional (acting on a transverse cross section). The classification of solid foods is even more hazy than that of fluid foods. There are two major groups: elastic and non-elastic. Visco-elastic foods, mostly of semi-solid and solid nature, form an important group of non-elastic foods.

4.1 Elastic solids

4.1.1 Hookean or linear elasticity

Elasticity is defined as the tendency of the product to recover upon unloading the shape and dimensions it had before loading. If there is no permanent deformation after unloading, the elasticity is said to be complete elasticity. Ideal or Hookean elasticity is characterized by a linear relationship between force (or stress) and deformation (or strain) starting at the origin (Fig. 2a). The body instantaneously returns to its initial form with no residual strain upon unloading.

![Stress vs Strain Graph](image)

**Fig. 2. Linear (a) and non-linear (b) elasticity: Stress-strain relationship**

Further, the linear relationship is retraced when the sample is unloaded. The ratio of tensile stress to strain for these so-called Hookean bodies is termed Young's modulus (E) or elongational modulus. The ratio between shear stress to shear strain in an ideal, linear elastic solid is called shear modulus (G) or rigidity.

4.1.2 Non-Hookean or non-linear elasticity

In reality, most elastic solids exhibit a non-linear or non-Hookean elasticity, in which case the stress is not proportional to strain, and the linear dependence of stress on strain
exists only at the lowest strain levels. In general, at higher strain levels the loading-and-unloading cycle yields two separate traces describing a hysteresis loop (Fig. 2b). Since the stress-strain relationship is curvilinear, the modulus of elasticity is frequently given as the tangent modulus, which is the slope of the stress-strain curve at any specified stress or strain.

4.2 Non-elastic solids

A material may show elasticity, linear or non-linear, if the applied stresses and corresponding strains are small. However, for large deformations most solids are non-elastic. Non-elastic products may exhibit failure when stress exceeds the strength of the body.

4.2.1 Failure

Failure may be seen as fracture or rupture.

4.2.1.1 Fracture : Cracking of hard materials such as hard cheese at low temperature ultimately resulting in two or more separate pieces is termed fracture. Elastic fracture is fracture without or with a very limited amount of flow (only in the region just around the crack) of the material, as in unripe fruit flesh, tubers etc., whereas plastic fracture is fracture accompanied by flow of material as may be seen in certain soft or semi-hard cheeses.

4.2.1.2 Rupture : This term refers to tearing (in pieces) of soft materials. Rupture point is sometimes defined as a point on the stress-strain or force-deformation curve at which the axially loaded specimen ruptures. The failure in rupturing materials such as certain cheese gels, cooked egg white etc. is characterized by a multitude of failure planes.

4.2.2 Plastic solids

Certain non-elastic products may show yield value and tend to flow when the stress exceeds this point (Fig. 3). Plasticity is found more frequently in semi-solid and soft products such as butter, spreads etc. rather than hard solids.

![Diagram of plastic flow](image)

**Fig. 3. Ideal plastic behaviour**
4.2.3 Viscoelastic foods

Failure resulting in rupture, fracture or plastic flow usually involves relatively large stresses and large deformation in solid foods. On the other hand, small deformation in most solids and semi-solid products may reveal what is known as viscoelasticity. Certain shear-thinning fluids such as age thickened sweetened condensed milk also exhibits viscoelasticity.

The reaction of a viscoelastic body to stress (or strain) consists partly of a viscous component and partly an elastic one. Since stress and strain are time-dependent, the response of the material is rate dependent. More discussion on viscoelasticity will be found later in this compendium.

5. CONCLUSION

Attempts have been made to classify food products on the basis of their rheological behaviour. However, the rheological phenomena in various foods are so complex that it is not simple to categorize them into distinct groups or classes. Yet the classification of foods based on the stress-strain rate relationship for fluid and semi-solid products, and stress-strain relationship for solids done in this chapter would greatly facilitate comprehending the rheological behaviour of various dairy and food products and relating it to their processing, handling and texture attributes.

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1. INTRODUCTION

Most fluid and semi-solid foods are either dispersions of solid particles in liquid media (i.e. colloids or suspensions), or of liquid droplets in dissimilar liquids (i.e. emulsions). Products like milk and cream are, in fact, both colloids and suspensions at once. In the stationary state the disperse entities may come together and form a network structure due to which the system responds viscoelastically when sheared at low rates. With increasing shear, the interlinked structure gradually breaks down until eventually, at sufficiently high shear, the fluids flow like viscous liquids. Thus pseudoplasticity or non-linear flow behaviour is the principal characteristic of most food dispersions including dairy fluids. In order to have a proper understanding of the rheological behaviour of non-Newtonian fluids, it would be helpful to consider in brief the theories of pseudoplasticity. This will be followed by a discussion on the flow behaviour of selected dairy fluids.

2. THEORIES OF SHEAR-THINNING

Several theories have been proposed to explain the flow behaviour of non-Newtonian fluids, but no single theory is entirely satisfactory, simply because food dispersions are very complicated systems. Most theories are based on the kinetics of the flocculation-deflocculation reaction which is influenced by Brownian movement and shear rate. The probability of collisions leading to flocculation due to shear between the disperse particles and that of collisions due to Brownian motion are dependent upon the number, type and size of the particles.

2.1 Theories based on flocculation-deflocculation kinetics

In these theories of non-Newtonian flow, the particles are assumed to form long chains when they come in contact with one another. Based on a model of rigid cylindrical rods as the particles forming chains Casson’s theory assumes that at very low rates of shear the chains move as single entities but at higher shear rates they break down into smaller units. Eventually at very high rates of shear the flocculated structure is completely broken down and the viscosity is due to the flow and interaction of individual particles.

Casson’s theory does not consider any interaction between chains. The assumption in Cross’s theory is that flocculated particles form random linked chains, the size of the latter depending upon the rate of shear. Link rupture is treated as a process influenced by both Brownian movement and shear, but link formation as affected by Brownian motion only.
The theories of van den Tempel and de Vries also assume that the viscosity of disperse system at any rate of shear depends upon the reversible flocculation-deflocculation reaction.

A dispersion (or emulsion) containing flocculated particles shows a higher viscosity than when the particles are unassociated. This is due immobilization of fluid in the interstices between particles within the flocculate structure. At a low shear rate, each flocculate moves as a single entity with a volume that is larger than the total volume of particles within the flocculate. The flocculates will break down to an increasing extent as the shear rate rises and hence, the volume of immobilized fluid will decrease with the result that the viscosity will also decrease.

Shear-thinning properties of polysaccharide solutions have been interpreted as a progressive mechanical disentangling of chains as shear rate increases. In the low shear rate domain, when the reciprocal shear rate is much larger than the time required for entangling two macromolecules, the mean entanglement density will remain constant. Beyond a critical shear rate, the entanglement density begins to drop, bringing about a reduction in viscosity. The reduction becomes more pronounced with increasing shear rate.

Systems such as soy milk or soy slurries characterized by suspended particles (protein bodies, fat droplets and cell wall fragments) in a viscous liquid become even more complicated when heated. Aggregation being the major effect of heating the flocculation-deflocculation based theories may better explain the the pseudoplasticity of these fluids showing a high apparent viscosity.

2.2 Other theories of pseudoplasticity

Williamson’s theory considers that in a pseudoplastic flow, part of the shearing force is used to break down the flocculated structure, while the remainder is used to produced flow at the higher rates of shear. The Impulse theory of Goodeve, an extension of Williamson’s theory, is based on the concept that two independent effects contribute to pseudoplasticity: a Newtonian effect where the shearing force is proportional to the rate of shear, and a thixotropic effect where the shearing force is constant irrespective of the shear rate. Links are formed between particles making contact with one another. These links are stretched, distorted and ruptured under the influence of shear. Redevelopment may then follow. Simultaneously, momentum or impulse is transferred from a moving layer to an adjacent slower moving layer and this is believed to be inversely proportional to the shear rate.

Based on a similar concept, the theory of rate processes assumed a structure composed of several flow units, Newtonian and non-newtonian. The Newtonian units in the model are not linked to similar units on the opposite side of a shear surface so that they shear readily, but the same is no true for the non-Newtonian units since they are connected to similar units on the other side of the shear surface.

The Derjaguin-Landau-Verwey Overbeek theory attempts to explain interactions between globules or spherical particles (after flocculation) in terms of the prevailing forces of repulsion and attraction. The repulsion forces are usually of electrostatic nature, their magnitude depending on the electric charge, electrolyte concentration, particle size, and the
distance between the particles \( \delta \). The repulsion energy determined by, besides the above factors, the polarity of the continuous phase, and the attraction energy which is not influenced by whether the continuous phase is polar or non-polar give rise to the net potential energy of interaction. This net energy has been stated to be related to the rheological behaviour of flocculated dispersions.

3. FLOW CHARACTERISTICS OF DAIRY FLUIDS

Many colloidal solutions showing non-Newtonian flow have a constant high viscosity at low shear rates and a constant low viscosity at high shear rates with a region of transition at intermediate shear rates. However, for most dairy fluids, the viscosity decreases progressively as the shear rate increases.

3.1 The shear-thinning behaviour

In a fluid like dairy cream, its randomly distributed fat globules may be considered to experience collisions resulting in flocculation under the influence of shear. The clumps may disperse as readily as they formed. With persistent shear, the particles will align themselves along the direction of flow and move in 'rafts'.

The particles have a tendency to return to a random arrangement. The degree of alignment will, therefore, depend on the net balance of the forces on the particles more or less according to Derjaguin-Landau-Verwey-Overbeek theory; the greater the shear stress, the greater the alignment and the lower the resistance to flow.

The above theory explains both the non-Newtonian behaviour and the phenomenon of 'overshoot' in liquid dairy product. Overshoot refers to the considerable build-up of stress reaching a peak value and then subsiding gradually to an equilibrium value, when a shear rate is imposed on a non-Newtonian fluid. The build up reflects the early crowding of the particles and to collisions, and the the peak value represents the maximum stress required to cause the mutual rotations of the adventitious clumps. The final apparent viscosity depends upon the ultimate balance between the restoring forces and the shearing forces. It will be lower for greater shearing forces.

3.2 Flow behaviour of milk

Since milk is a dilute solution of lactose containing relatively small amounts of proteins and fat, it is essentially a Newtonian fluid, its relative viscosity being about 1.5. Buffalo milk has a slightly higher viscosity (2.3 m Pa.s at 20°C) than that of cow milk (2.0 m Pa.S). It should, however, be noted that the values may vary appreciably depending on several factors.

At low shear rates (<10 s\(^{-1}\)) and temperatures below 40°C, milk exhibits a non-Newtonian behaviour nevertheless.

Upon heating above the pasteurization temperature denaturation of beta-lactoglobulin and accompanying structural changes in casein micelles and fat globule membrane cause the milk viscosity to go up. In case of skim milk, however, a decrease in viscosity is noted upon
heating up to 130° C followed by cooling to ambient temperature, but the pattern is reversed above 130°C. Nevertheless, such viscosity changes are relatively minor unless the milk colloid is destabilized at high temperatures.

Homogenization of milk, resulting in a greatly increased fat globule surface with adsorbed protein layer increases its viscosity. But the absence of immunoglobulins from the newly formed globule surfaces prevent globule clumping and hence, the non-Newtonian nature of the milk decreases.

3.3 Rheology of concentrated milks

Milk concentrated by evaporation retains its Newtonian character up to about 30% total solids especially at temperature above 40°C. But if it is concentrated by Ultrafiltration (UF), the product is typically pseudoplastic.

Fresh sweetened condensed milk is only slightly pseudoplastic, but the age-thickened product is distinctly shear-thinning, somewhat similar to unsweetened UF retentate. The viscous and elastic components of this perceivably viscoelastic product have been found to undergo considerable quantitative change during storage.

3.4 Rheology of cream

The major difference between milk and cream is that the fat-SNF ratio as well as the fat content is such higher in the latter. The fat content of cream is the major determinant of its rheological behaviour, since the fat globules tend to clump together during shearing. A thick cream subjected to constant shear rate measurement using a rotation viscometer will reveal a prominent overshoot especially when the shear rate is very low (< 0.1 s⁻¹). Raw and pasteurized creams show a power law behaviour but only up to a certain shear rate; at higher shear rates the product tends to get destabilized.

The rheological behaviour of many disperse systems like cream may be appreciably influenced by the method of measurement. Rotation viscometers, for instance, give results that are greatly influenced by the clumping phenomenon whereas the measurements by dynamic or oscillation techniques (in which strain produced by a small sinusoidally varying stress function is measured) are the least affected by clumping.

The state of fat in cream as determined by its temperature history governs, to a considerable extent, its flow properties. Rapid cooling and lower temperature attained result in slower solidification of the fat and slower recovery of the 'thickness' of the cream. Ageing resulting into a structure build-up in cream imparts a definite thixotropy to it.

3.5 Ice-cream mix rheology

As compared to milk, ice-cream mix is far richer both in fat and SNF, although its fat content is lower than that of cream. Due to its stabilizer content and higher concentration of non-fat solids the continuous phase of ice cream mix is more viscous than the serum of cream (or milk). Fat globule aggregation on application of shear coupled with the
shear-thinning properties of hydrocolloids make the ice cream mix strongly pseudoplastic. It obeys the de Waele law over a wide range of shear rates (from $<0.1 \text{s}^{-1}$ to above $100 \text{s}^{-1}$).

3.6 Flow behaviour of yoghurt

Rheologically there are two types of yoghurt: set yoghurt and stirred yoghurt. While the former is a typical solid gel, the latter is in essence a fluid product. Stirred yoghurt is obtained by partial structural break down through agitation of the set product. It flows like a thin, pseudoplastic paste. The shear sensitive viscosity of this thixotropic product falls with continuous shearing until eventually a constant value is approached asymptotically. If stress-shear rate measurements are made beginning from zero shear rate, a yield value is observed and the increasing stress more or less follows the Herschel-Bulkley model. The thixotropic nature of the product, however, makes the reverse cycle to show a nearly linear fall of stress to the original yield value.

4. CONCLUSION

Most fluid foods including dairy fluids like cream, ice cream, mix, stirred yoghurt and liquid infant foods are dispersions and/or emulsions showing a complex flow behaviour. Shear thinning is a common feature of these products. Several theories have been advanced to explain this phenomenon, but no single theory can adequately elucidate the flow properties as observed in practice. However, flocculation or aggregation and deflocculation or disaggregation of the dispersed particles under the influence of shearing and other forces are generally recognized to be the basic mechanism underlying the shear-thinning behaviour.

While milk is Newtonian fluid for all practical purposes (except at very low shear rates and low temperature), most other dairy fluids exhibit a shear-thinning behaviour following the power low model or the Herschel-Bulkley model. At low shear rates, some of these products reveal a definite overshoot. Thixotropy often characterizes products such as aged cream, thickened condensed milk, yoghurt and ice cream mix.

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VISCOELASTICITY OF FOODS AND RHEOLOGICAL MODELS

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1. INTRODUCTION

Most semi-solid and solid foods including cheese, pancer, sweetened condensed milk, ice-cream and indigenous dairy products are viscoelastic in nature. The time dependency of stress-strain relationship results in a behaviour called viscoelastic, which combines liquid-like and solid-like characteristics i.e. these bodies combine the properties of both viscous and elastic materials. The ratio of elastic to viscous properties depends on the time scale of the deformation. At short time scales its behaviour is mainly elastic: a test piece (almost) regains its original shape after the stress applied to it is removed. At long time scales the behaviour is mainly viscous: (most of) the deformation remains after the stress is removed.

2. MECHANICAL MODELS

Several models have been developed to describe the viscoelastic behaviour of materials. There are two basic viscoelastic models viz. Kelvin and Maxwell. Other complex viscoelastic behaviours are described by using combinations of these basic models.

2.1 Kelvin model

The Kelvin model employs the spring (elastic component) and dashpot (viscous component) in parallel. In this stress is the sum of two components of which one is proportional to the strain and the other is proportional to the rate of shear. Since the elements are in parallel they are forced to move together at constant rate. When a constant load is applied to Kelvin model, initially a retarded deformation is obtained followed by a final steady state deformation. When the load is removed the Kelvin model recovers completely but not instantaneously. The model is expressed mathematically as:

\[ \varepsilon_t = \frac{\sigma_o}{E} \left(1 - e^{-t/T_{ret}}\right) \]

where, \( \varepsilon_t \) is strain at time \( t \), \( \sigma_o \) is applied stress, \( E \) is elastic modulus and \( T_{ret} \) is retardation time.

2.2 Maxwell model

The Maxwell model employs a spring and dashpot in series. In this model the deformation is composed of two parts, one purely viscous and the other purely elastic. When a constant load is applied to Maxwell body, instantaneous elastic deformation will take place followed by continuing viscous flow, which will continue indefinitely as it is not limited by
the spring component. When load is removed, the Maxwell body recover instantly but not completely. The Maxwell body shows stress relaxation but Kelvin body does not. The stress-strain-time relationship in Maxwell model can be given as:

\[ \varepsilon_t = \sigma_0 / (E_d (1 - e^{-\nu T} \text{rel}) + E_e ) \]  

\[ \text{.........(2)} \]

where, \( \sigma_t \) is stress at time \( t \), \( \sigma_0 \) is fixed strain, \( E_d \) is elastic decay modulus and \( T_{\text{rel}} \) is relaxation time and \( E_e \) is equilibrium modulus.

2.3 Burgers model

This 4-element model is one of the best known rheological model which has been used to predict the creep behaviour in a number of materials. The model is composed of a spring and dashpot in series with another spring and dashpot in parallel. When a burger's body is subjected to constant load, there is instantaneous deformation (\( E_o \)) followed by retarded flow. When the load is removed there is instantaneous recovery followed by incomplete and slow recovery. The stress-strain time relationship can be given as:

\[ \varepsilon_t = \sigma_0 / (E_o + \sigma_0 / E_t (1 - e^{-\nu T} \text{ret}) + \sigma_e t/\nu) \]  

\[ \text{.........(3)} \]

In terms of compliance function \( J_t \) which is reciprocal of Young's modulus (\( E \)) the above equation can be given as:

\[ J_t = J_o + J_e (1 - e^{-\nu T} \text{ret}) + t/\nu \]  

\[ \text{.........(4)} \]

Where, \( J_o \) is \((1/E_0)\) initial compliance, \( J_e \) is \((1/E_e)\) retarded compliance and \( t/\nu \) is Newtonian compliance.

2.4 Generalised Maxwell model

A generalised Maxwell model is composed of \( n \) Maxwell elements with a spring in parallel with \( n+1 \)th element. The elastic modulus \( E_e \) of last spring corresponds to the equilibrium modulus in the stress relaxation test. The stress-strain time relationship is given by:

\[ \varepsilon_t = \sigma_0 (E_{a1} + e^{-\nu T_1} + E_{a2} e^{-\nu T_2} + \ldots + E_{an} e^{-\nu T_n} + E_e) \]  

\[ \text{.........(5)} \]

where \( T_1, T_2, \ldots, T_n \) are relaxation times.

2.5 Generalised Kelvin model

Experimental data on many viscoelastic materials including biological materials have shown more than one relaxation time or retardation time. For these materials, complete behaviour cannot be represented by a singly Maxwell or single Kelvin model or even 4 elements model. Each of these models have only one time constant. To represent the viscoelastic behaviour more realistically a chain of Kelvin models, each with its own time of retardation is assumed and the model is called a generalized Kelvin model. It consists of "n"
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Kelvin elements connected in series with an initial spring and final viscous element. The equation for generalised kelvin model is:

\[ \varepsilon_t = \sigma_t \left\{ \frac{1}{E_s} + \frac{1}{E_\eta} \left( 1 - e^{-t/T_1} \right) + \frac{1}{E_\eta} \left( 1 - e^{-t/T_2} \right) + \ldots \right\} \]

\[ \frac{1}{E_m} \left( 1 - e^{-t/T_m} \right) + \ldots \]

where \( T_1, T_2, \ldots, T_n \) are relaxation times.

2.6 Plasto - visco - elastic or Bingham model

A more common type of body is the plasto-visco-elastic or Bingham body. When the stress is applied which is below the yield stress the Bingham body reacts as an elastic body. At stress values beyond the yield stress there are two components. One is constant and is represented by the friction element and the other is proportional to the shear rate and represents the viscous flow element. In a creep experiment with stress not exceeding yield value, the creep curve would be similar to the one for a plastic body. When the shear stress is greater than the yield stress, the strain increases with time similar to the behaviour of a Maxwell body. Upon removal of stress at time the strain decreases instaneously and remains constant thereafter. The decrease represents the elastic components and the plastic deformation is permanent.

3. VISCOELASTIC CHARACTERISATION OF MATERIALS

There are a number of tests which may be used to study viscoelastic materials and determine the relation among stress-strain-time for a given type of deformation and a given type of loading pattern. The most important tests include stress relaxation, creep and dynamic tests.

3.1 Stress relaxation

In stress relaxation test the specimen is suddenly brought to a given deformation (strain), and the stress required to hold the deformation constant is measured as a function of time. The results are expressed in terms of time dependent modulus \( E_t \) in tension or compression, \( G_t \) in shear or \( K_t \) in bulk compression. The rheological models representing stress relaxation are Maxwell model and generalised Maxwell model. One of the most important viscoelastic parameters which can be obtained from stress relaxation test is the relaxation time. It is the time at which the stress in the body resembling a maxwell model decay to \( 1/e \) of initial stress. It is the measure of the rate at which a material dissipates stress after receiving a sudden force. There are a number of methods for treating experimental data on stress relaxation and finding the relaxation time.

The method of successive residuals involves as the first step in analysis of stress relaxation data plotting the logarithm of stress vs. time. If the plot were linear, the behaviour of the material is Maxwellian and the time of relaxation can be determined from the slope of the straight line. In most cases the plot of logarithm of stress vs. time is non-linear, indicating that the rheological behaviour cannot be represented by a single Maxwell element but an
array of Maxwell elements connected in parallel is required. This is the most commonly used method of calculating relaxation times.

3.2 Creep measurement

In this test the stress is suddenly applied and held constant, and strain ($\gamma$ or $\varepsilon$) is measured as a function of time. For a viscoelastic material the slope ($\frac{d\gamma}{dt} = \gamma$) gives (from $\sigma/\gamma$) an apparent viscoelasticity. The deformation $\gamma_0$ is a measure of the elastic part. From the instantaneous shear modulus $G_\gamma$ may be calculated ($\sigma/\gamma_0$) or the instantaneous compliance $J_\gamma (\gamma_0 /\sigma)$. The whole curve gives $J_\gamma$, which, in principle, can be calculated to yield $G_\gamma$. The rheological model to represent the creep behaviour is the Kelvin model and 4 elements Burgers model. Creep measurement are very useful for studying stand up properties of foods.

4. DYNAMIC MEASUREMENTS

Despite the simplicity of creep and stress relaxation experiments, there are two disadvantage in these tests. The first disadvantage is that in order to obtain complete information about viscoelastic behaviour of the material, it is necessary to make measurements over many decades of time scales. This in addition to prolonging the experiment may cause chemical and physiological changes in the specimen which will affect the physical behaviour of the material. The second disadvantage is the impossibility of having a truely instantaneous application of load or deformation at the beginning of the experiment.

These disadvantages can be overcome by dynamic tests in which the specimen is deformed by stress which varies sinusoidally with time. The time scale of the measurement can be varied by changing the frequency ($\omega$) of the oscillation. Dynamic measurement are a powerful method for research on viscoelastic systems. One can determine both the elastic and viscous components in the reaction of a material an applied stress or strain over a wide range of time scales.

In a dynamic experiment in which the shear strain $\gamma$ is varying sinusoidally, the latter is given by

$$\gamma(t) = \gamma_0 \sin (\omega t)$$

...(7)

where $\gamma_0$ is the maximum shear strain. The strain is associated with a sinusoidally varying shear stress ($\sigma$) as follows:

$$\sigma(t) = \sigma_0 \sin (\omega t + \delta)$$

...(8)

where $\sigma_0$ is the maximum stress and $\delta$ is the phase angle between the deformation and stress. This phase difference originates from the viscous properties of the material. For an ideally elastic solid, $\sigma$ is in phase with $\gamma$. For an ideally viscous fluid $\sigma$ is $\pi/2$ radians out of phase, then $\delta$ equals $\pi/2$. For a viscoelastic material like a milk gel, $\delta$ has a value between $\sigma$ and $\pi/2$. 

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Within the linear region $\sigma_0$ is by definition proportional to $r_0$. The elastic part of the stress, which is the part of the stress in phase with strain, corresponds to the *storage modulus* $G'$, which is defined as:

$$G' (\omega) = (\sigma_0/\gamma_s) \cos \delta.$$  \hspace{1cm} (9)

It is the measure of the energy stored and subsequently related per cycle of deformation. The viscous part of the stress which is part of the stress out of phase with the strain, corresponds to the *loss modulus* $G''$, which is defined as

$$G'' (\omega) = (\sigma_0/\gamma_s) \sin \delta.$$  \hspace{1cm} (10)

It is the measure of the energy dissipated as heat per cycle of deformation. The ratio of $G''$ to $G'$ is $\tan \delta$:

$$\tan \delta (\omega) = G'' (\omega) / G' (\omega).$$  \hspace{1cm} (11)

A higher $\tan \delta$ means that the material behaves in a relatively more viscous and less elastic manner.

5. CONCLUSION

Viscoelasticity is a combined solid-like, liquid-like behaviour of materials. Most semi-solid and solid foods are viscoelastic in nature. Several rheological models and test methods are now available to characterize the viscoelasticity of foods. Viscoelastic characteristics of foods are of great importance to the manufacturers, the trade and the consumers as these properties affect 'eating quality', usage properties such as ease of cutting, spreading and melting characteristic and handling and packaging characteristics.

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PSYCHORHEOLOGY OF FOODS

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1. INTRODUCTION

Psychorheology is the scientific study of man's perception of texture. It may be divided into two major areas: qualitative and quantitative. Qualitative work concerns the attributes of texture to which man responds, the structure of his mental lexicon of texture descriptors and the clusters of similar meaning texture descriptors. Quantitative work may consider mathematical relations between pairs of texture descriptors, or functions relating one or several subjective textural properties. To date the major thrust of quantitative psychorheology has been to ascertain the class of functions relating mechanical to subjective properties and through experimentation to quantify the parameters of those functions. It is now well established that the psychorheological models are important in texture studies.

Subjective - objective interactions for the food industry suggest a multistage process:

a. Selection of an appropriate subjective attribute.
b. Selection of an instrument measure or set of measures that produces sensory perception.
c. Hypothesise equations relating subjective and instrumental variables.
d. Estimation of parameters of that equation by least square procedure, and
e. Estimation of goodness of fit and function to the actual data by means of correlations and F-ratios (Moskowitz, 1981).

2. SENSORY MEASUREMENT OF FOOD TEXTURE

Texture is basically a sensory attribute perceived as a response to different kinds of physical and physio-chemical stimuli. As discussed earlier in Part I, no instrument can perceive, analyse, integrate and interpret at the same time a large number of texture sensations. Because of these limitations of instrumental techniques sensory evaluation of texture profile is extremely valuable. Sensory evaluation is made by the pleasure centre in the brain and provides important information, either analytical or objective, and psychological reaction to the product.

Szczesniak (1963) classified the textural properties into three main groups, namely mechanical, geometrical, and other properties related to the content of fat, moisture etc. The mechanical attributes (except adhesiveness), measure the response of food to stress and are related to the ability of the food to resist deformation under applied forces. The arrangement of constituents of food including the size and shape of particle orientation
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refers to geometric characteristics and it determines gross- and micro-structure of food. Other characteristics such as moisture and fat contents contribute to the phenomena observed during instrumental analysis. Civele and Szczesniak (1963) described the physical and sensory definitions of mechanical characteristics (Table 1) which have widely been accepted for texture profile analysis.

**Table 1. Definition of textural characteristics**

<table>
<thead>
<tr>
<th>Properties</th>
<th>Physical</th>
<th>Sensory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness</td>
<td>Force necessary to attain a given deformation</td>
<td>Force required to compress a substance between teeth</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>Extent to which a material can be deformed before rupture</td>
<td>Degree to which a substance is compressed between the teeth before it breaks</td>
</tr>
<tr>
<td>Springiness</td>
<td>Rate at which a material returns to its original condition</td>
<td>Degree to which a product returns to its original size</td>
</tr>
<tr>
<td>Secondary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fracturability</td>
<td>Force with which a material fractures</td>
<td>Force with which a sample crumbles</td>
</tr>
<tr>
<td>Chewiness</td>
<td>Energy required to masticate a food to a state ready for swallowing</td>
<td>Time required to masticate the sample to a state ready for swallowing</td>
</tr>
<tr>
<td>Gumminess</td>
<td>Energy required to disintegrate a semisolid food to a state ready for swallowing</td>
<td>Denseness that persists throughout mastication</td>
</tr>
</tbody>
</table>

Sensory texture profile is defined as the organoleptic analysis of the texture complex of a food in terms of its mechanical, geometrical, fat and moisture characteristics, the degree of each present, and the order in which they appear from first bite through complete mastication. The data on these parameters is generally collected using either interval or ratio scales.

3. INSTRUMENTAL EVALUATION OF TEXTURE

As stated earlier, the instrumental methods that have been used to evaluate the rheological properties of food may be empirical one or fundamental ones. Empirical methods include imitative ones the Texture Profile Analysis (TPA) method employing the Texturometer as described by Friedman et al. (1963). The TPA has also been performed by many workers using Instron Universal Testing Machine. In these methods, mostly food samples are compressed between two plates using an Instron testing machine or a comparable apparatus and the force is recorded as a function of the compression. Until now, no standardization of these tests has been made and many different executions of the tests have been described. Examples of differences are: shape and size of the test piece, size of the plates, treatments of the plates to increase or decrease the friction between the plates and
the test piece, compression rate and temperature. One or more of the following parameters are usually derived from these tests:

- Force (or stress) at a given compression.
- Force at the first maximum in the force-compression curve (often designated as fracture force).
- Initial slope (or modulus) of the force-compression curve.
- Compression at the first maximum in the force-compression curve (often designated as fracture compression).
- Work done until a given compression.
- Height recovered after deformation.
- Adhesive force during ascending motion after compression.

4. PSYCHORHEOLOGICAL MODELS

Psychorheological models consist of a mathematical expression relating sensory rheological data to the corresponding mechanical data. These two sets of data are usually considered as output and input respectively. Associations between subjective and objective texture measurement may be expressed by graphical or mathematical/statistical terms. Various correlation coefficients quantify the relation between variables.

Using regression analysis, one can ascertain the relation itself, beyond developing a measure of relatedness of two variables with the assumption of unilateral casualty. Regression analysis helps the experimenter to: (a) select a variables, and (b) to estimate the parameters of that equation by statistical analysis. Often linear equation, as given below, adequately describe the sensory - instrumental relation (Moskowitz, 1981):

\[ S = k_0 + k_1 x_1 + k_2 x_2 + \ldots + k_n x_n \]  \hspace{1cm} (1)

where, S is the sensory response and \( x_1, \ldots, x_n \) are the intensities of physical variables.

However, for foodstuffs that greatly differ in texture, the relationship is not always linear. Moskowitz (1981) demonstrated a potential problem in correlating hedonic responses (likes/dislikes) from sensory panels with physical measurement of food quality. The problem arises in that physical measurement are usually linearly correlated to intensity whereas panel assessment based on hedonic response is non-linear with intensity. He suggested using a quadratic equation. This model should contain all first and second order terms (including cross products when more than one attribute is measured with hedonic responses) such as:

\[ S = k_0 + k_1 x_1 + k_2 x_2 + k_3 x_1 x_2 + \ldots + k_4 x_1 + k_5 x_2 + \ldots \]  \hspace{1cm} (2)

The above full quadratic equation is less parsimonious than a simple linear equation. Nevertheless, it permits non-linearities and permits one to model some interactions among the physical variables.

In other instances, better fitting equations are developed with a non-linear combination of physical variables. Some of the possible equations are given below:
\[ S = k_0 + k_1 x_1 + k_2 x_2 + \ldots \] ..........................(3)

\[ S = k_0 e^{k_1 x_1 + k_2 x_2 + \ldots} + \ldots + c^{k_3} \] ..........................(4)

The data obtained using interval scale requires a model which can transform ratios of instrumental values to difference (or intervals) of perceived texture magnitude. The logarithmic transformation is the preferred function to transform ratios of one variable into difference of another. Quite often, therefore, a logarithmic function of the form:

\[ S = k \log I \] ..........................(5)

or

\[ S = k \log (I + I_o) \] ..........................(6)

relates interval scale value assigned to a texture stimulus \( S \) to the physically measured value assessed by an objective instrument \( I \). The relation may not be perfectly linear in logarithmic coordinate, in which case the additive constant \( I_o \), straightens out the function and renders the relation linear. In some instances \( I_o \) may have actual physical meaning, for it represents a "threshold" value.

When the sensory data is obtained with ratio scale, data can be related with instrumental data using a power function:

\[ S = k I^n \] ..........................(7)

The function becomes a straight line in log-log coordinates \((\log S = \log k + n \log I)\), so that the exponents \( n \) may be calculated from the slope of the line, and the multiplier \( k \) can be calculated from the intercept.

The exponent is an index of how rapidly sensory magnitudes increase with stimulus magnitudes. When \( n \) is 1.0 a 10 fold change in sensory magnitude results from a 10 fold change in physical intensity. When \( n \) exceeds 1.0 as in the case of the perceived pain of electrical shock \((n = 2)\), sweetness of sucrose \((n = 1.3)\) and roughness of sand paper \((n = 1.5)\), then physical ratios of magnitude are expanded. Thus, a 10 fold increase is expanded by the sensory system to a 100 fold increase in the pain of electric shock (perceptually), 20 fold increase in sweetness, and 3-fold increase in roughness, respectively. Where \( n \) is less than 1.0, as is the case of perceived viscosity \((n = 0.5)\) the perceptual system contracts the physical range, so that a 10 fold change in apparent viscosity measured with viscometer is perceived only as a 3-fold change. The prime attractiveness of the lower function is that it relates percentage changes in instrumental readings to percentage changes in sensory responses.

For textural attributes a number of power functions have been published that illustrate the dynamic of texture:

\[ \text{Viscosity}, \ S_v = k V_p^{0.3} \] ..........................(8)

where, \( S_v \) is the subjectively perceived viscosity and \( V_p \) is apparent physical viscosity of solutions of gums.

\[ \text{Hardness}, \ S_h = k (\text{ME})^{0.41} \] ..........................(9)
\[ S_h = k \text{ (US)}^{0.61} \] ..........................(10)

\[ S_e = k \text{ (ME)}^{0.72} \] ..........................(11)

\[ S_e = k \text{ (US)}^{0.53} \] ..........................(12)

where, \( S_h \) is subjective hardness, \( S_e \) is subjective crunchiness, ME is modulus of elasticity and US is ultimate strength.

\[ F_r = 27.638 \text{ H}^{0.51} \quad (R = 0.926) \] ..........................(13)

\[ F_r = 11.275 \text{ H}^{0.50} \cdot C^{0.08} \cdot \text{Spr}^{0.47} \quad (R = 0.94) \] ..........................(14)

where, \( F_r \) is sensory firmness of khoa, \( H \) is Instron TPA hardness, \( C \) is TPA cohesiveness and \( \text{Spr} \) is TPA springiness (Patil et al., 1990).

The correlation of instrumental and sensory assessments of texture must be made with care so that conclusions based upon studies within restricted limits are not used as a basis for wider generalizations. When analysing two sets of data the following points should be considered:

a. The significance of the correlation coefficient
b. What properties are measured by the instruments employed
c. The test conditions
d. Homogeneity of the samples
e. Physiological and psychological factors influencing panel members in their sensory assessment
f. Method of data interpretation
g. The experience of the panel
h. The reliability of the instrumental test.

Several problems / difficulties are faced in the study of psychophysics. There is no universal agreement on the best way of conducting sensory texture measurement and different research groups use different methods. Difference exist in the degree of panel training or sophistication in the type of scales used, in the physical conditions surrounding the test situation, and whether or not a standard is supplied as a reference. All these factors affect correlations with objective measurements.

5. CONCLUSION

Texture is a sensory property which generally has been described qualitatively and only recently have quantitative models been developed and applied. These psychophysical models consist of a mathematical expression relating sensory rheological data to the corresponding mechanical data. The advantage of developing this type of quantitative analysis of texture is that samples of varying characteristics can be evaluated objectively and immediately assessed for their consumer preference. Psychophysical studies can potentially revolutionize the quality assurance programme for greater reliability and simplicity.
REFERENCES


1. INTRODUCTION

Apart from economic considerations, consumer acceptance of dairy food products may be attributed to a variety of factors such as appearance (colour, size), flavour and texture. Textural characteristics are an important factor in overall quality of many dairy products. Unless these quality attributes meet the standards that the consumer expects, the product will be rejected regardless of its nutritional value.

2. TEXTURE AND ITS INSTRUMENTAL PROFILES

A comprehensive definition of texture be given as below:

"The textural properties of a food are that group of physical characteristics that are sensed by the feeling of touch, are related to the deformation, disintegration and flow of food under application of force".

While the subjective measurement of sensory properties are accomplished by the use of sense of touch or feel by the human hand and mouth, the objective techniques refer to measurement of the properties only indirectly. In spite of certain limitations such as high cost, skilled operation, calibration of instruments, the instrumental approach remains superior to subjective measurements because of sensitivity, reproducibility and versatility.

The textural properties of foods are greatly influenced by the internal structure, composition (protein, total solids), size and shape, and their interrelationships. It is, therefore, not possible to obtain an overall index of these properties in a single measurement.

Objective measurements of texture generally measure force or work or both which are functions of mass, time and deformation. The following textural profile properties are often measured in modern texture analyses:

a. Hardness
   The force necessary to attain a given deformation (peak force during the first compression cycle)

b. Cohesiveness
   The rate of disintegration under compression strength (ratio of positive area during the second compression to that of first compression)
c. Adhesiveness
   The work necessary to overcome the attractive forces between the surface of the food
   and other surface of contact (negative peak area for the first cycle decompression)

d. Elasticity
   The rate at which a deformed material goes back to its undeformed condition, after
   the deforming force is removed. (The height that the food recovers during the time that
   elapses between the end of the first bite and start of the second bite)

e. Gumminess
   The energy required to disintegrate a semi-solid food product to a state ready for
   swallowing (hardness & cohesiveness)

f. Chewiness
   The energy required to masticate a solid food product to a state ready for swallowing
   (gumminess x springiness)

3. TYPES OF TEXTURE INSTRUMENTS

   There exists a diverse range of instruments for measuring texture properties of dairy
   and food products. Some of the equipments are described below:

3.1 Wire Cutting Devices

   A wire driven at a constant speed to cut the sample is used for certain dairy products.
   An advantage is that the sample area in contact with the wire is constant throughout the test,
   which minimizes the effect of friction and adhesion between the product and the test cell
   surfaces.

3.2 Circular cutting devices

   The Cherry-Burrel Curd tension meter is used in the dairy industry to determine curd
   tension of milk and firmness of cottage cheese. A circular blade is driven at a constant speed
   of 2.54 cm per 7.5 sec. to cut the curd.

3.3 Cone Penetrometer of varying dimensions

   It consists of a cone of varying dimensions which is allowed to penetrate chilana,
   paneer, khoa or any other soft dairy product. The hardness values are read out on a
   mechanical linked graduated scale in terms of mm penetration.

3.4 Pea Tenderometer

   It consists of a grid of shearing blades (test cell) rotated at constant speed through a
   second grid suspended, so that the force on the second grid is counter balanced by a
   pendulum which is displayed by a pointer on a graduated scale. It is widely used by the pea
   industry.
3.5 The Warner-Bratzler Shear Test

A cylindrical sample usually 2.5 cm. in dia. is placed in a triangular hole in a thin blade of 0.25 cm. thickness cut by pulling the blade through a slot and the sheer force indicated by a spring scale. It is widely used for meat products.

3.6 Kramer shear press

It consists of a hydraulic press where the ram speed can be selected to complete its down stroke in 15 to 100 seconds. The ram operated by a hydraulic pump drives the moving components of the texture test cell into stationary components supported by the press frame. It is based on the principle of a multi-blade shear compression cell. Because of limitation of control by ram speed, the instrument does not give precise and accurate reading of force exerted.

3.7 Instron Machine

The Instron universal machine is an instrument for measuring texture through tension and compression testing within the force range of <1N-5kN. It is a versatile instrument for application in research, development and quality control laboratories. It comprises of a standard load frame and drive unit, a load weighing system and a microprocessor based control system. A beam carrying a load cell (moving cross head) is located between the base unit and the fixed crosshead at the top of the frame. The crosshead moving in vertical direction at a selected speed is supported and driven by two lead screws. It contains a force sensing and recording system which measures the force during the test and transmits them to a strip chart recorder. The Instron can be programmed for automatic return, cycling and relaxation test etc.

3.8 The Ottawa Texture Measuring System

This machine is similar to the Instron Machine in design and operation except that it uses a single screw as drive instead of twin screws. The Ottawa cell consists of a rectangular metal box containing 8 or 9 thin stainless steel rods. The sample is compressed by a plunger and sheared and extruded through a wire-grid. It offers operational flexibility for research and quality control laboratories. It uses modern electronic system to record force, deformation and time precisely.

3.9 General Foods Texturometer

This instrument imitates the chewing action of the mouth for mastication of foods. The chewing forces are detected by strain gauges with the help of a position transducer and displayed on an oscilloscope. This helps ascertain the force required for teeth penetration into the food, thus reflecting the food texture.

3.10. Other Instruments

The curd tension, curd firmness, consistency of cheese etc. can be determined by various techniques especially milk curdo-meter, containing a star shaped knife attached to a
balance. Other texture measuring devices employed for milk products include ball and needle penetrometers, extenders, gelographs etc.

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1. INTRODUCTION

Solid dairy products such as butter and cheese are valued for their textural characteristics. Admittedly, the texture of other products, solid, semi-solid or fluid, is an equally important determinant of their overall sensory acceptance, but probably because of their solid nature and its variability have attracted greater attention during the past 50 years so far as the instrumental measurement of their texture and rheology is concerned. Several empirical methods have been developed in attempts to best describe the products' rheology in relation to their textural properties. Considerable efforts have also been devoted to obtain information on the fundamental rheological properties of cheese and butter. However, owing to the complexities of the product texture, progress made in this regard is rather limited. Nevertheless, recent developments in rheological instruments hold out a definite scope for generating valuable information on the basic rheological parameters of these products. In the context of Indian dairy industry, texture and rheology of certain solid and semi-solid products such as paneer, khoa, chhana and milk sweets have been recognized to play an important role in their acceptance which, in turn, has a great bearing on the success of their production in modern dairy plants.

2. RHEOLOGY OF CHEESE

2.1 Early developments

Ever since the early reports pertaining to the Davis's plastometer devised to measure deformations in cheese, butter etc. under compression several different rheometers have been developed. These include Devis's apparatus for measuring the crushing strength of cheese, a spherical compression device of Scott Blair and Coppen (employing a 3.8 cm sphere for compression of cylindrical cheese samples), Caffyn's ball compressor and secilometer (a wire cutting apparatus), and several penetrometers. Some of these principles were incorporated into certain commercial instruments for routine analysis. Hoeppler consistometer was one such instrument also used for deriving certain fundamental measurements e.g. viscosity and elastic modulus of hard and semi-hard cheese varieties. Studies to correlate measurements obtained with instruments and sensory texture properties of cheese yielded varying results, the correlations generally being high for hardness but low for springiness and other attributes.

During the late fifties and sixties, considerable interest was witnessed in employing rheological measurements for process control (in terms of raw cheese ingredients etc.) in the manufacture of processed cheese. This interest has been subsequently maintained to a great
extent primarily because of increasing process variables and sustained and growing demand for this product.

2.2. Recent developments

With the advent of the new generation rheological instruments such as the Instron machine, Ottawa texture measuring system, Bohlin's rheometer and several texture analysers (e.g. Steuren's, Micro Stable Systems etc.), rheological measurements of cheese has undergone a dramatic change. Instruments providing non-destructive dynamic measurements have been used for viscoelastic characterizations of cheese offering better understanding of cheese texture.

In spite of the impressive advances registered regarding the rheology measuring systems, there is a long way to go before rheological measurements become a substitute for sensory texture. There are several reasons for this, which have been discussed elsewhere in this volume. But one more specific in relation to cheese reason is its nonhomogeneity arising primarily from its constituents and the manufacturing process. A recent IDF publication provides an extensive review of various aspects of the rheology and fracture properties of different varieties of cheese, where the anisotropic nature of cheese resulting from pressing of curd, considered a major factor contributing non-homogeneity.

2.3. Measurements on cheese in different deformation modes

Hard and semi-hard cheese varieties have been subjected to rheological measurements most frequently by uniaxial compression and to a lesser extent by deformation in tension or shear between two parallel plates. Sometimes three point bending of a cylindrical cheese sample has been employed to imitate the deformation seen while grading a cheese plug. The quantitative characterization of cheese can be achieved in terms of various moduli especially the compression modulus as well as the relative deformation at fracture and fracture stress in a compression test. Toughness or the energy of fracture (the energy required from the onset of compression till the cheese sample fractures) is also a useful parameter.

Texture profile analysis (TPA) using compression between parallel plates has been extensively used for cheese texture characterization but the TPA parameters have been stated to be of only a limited value in cheese texture characterization.

Biaxial extensional viscosity determined by using compression between parallel discs has been found to be particularly applicable to process cheese. The so-called lubricated squeezing flow technique for the determination of extensional or elongational viscosity has been used to measure the melting properties of processed cheese as also of Mozzarella cheese. To a limited extent oscillation measurements have been made on Gouda and other cheeses to obtain dynamic moduli reflecting the viscoelastic character of the product.

2.4 Factors affecting cheese rheology

Cheese is a composite material. Its major constituents para-casein, fat and the aqueous phase, contribute each in a specific way to the structure and hence to the rheology of cheese. The para casein matrix imparts the product solidity to through formation of 3-dimensional
structure. Thus composition is among the most important factors influencing cheese rheology. The moisture, fat and protein contents are major compositional variables in cheese. Fat is a key contributor of the temperature-caused variation in the rheological properties of cheese. The pH of Gouda cheese has been observed to affect the stress-strain curves as well as the loss angle (\tan \delta) of the product. These rheological parameters of ripened cheese such as Gouda also vary with the period of ripening.

2.5 IDF recommendations

Regarding the rheological methodology for cheese the following are among the salient recommendations made by IDF:

a. A method that yields real and unequivocal rheological or fracture parameters should be used so that the results do not vary with test-piece size or with small variation in test conditions.

b. The sample preparation should be such that it does not subsequently alter the product properties.

c. The type, extent and time scale of deformation should be in accordance with the conditions during the actual use of the cheese (e.g. eating, cutting or storage).

d. Different mechanical methods may be used for the purpose of comparison and visible changes during deformation should also be observed.

3. BUTTER RHEOLOGY

Rheology measurements of butter are important from two main points of view: first, spreadability of butter as a functional texture attribute, and second, its pumpability or handling convenience. The most relevant factor in this connection is the high temperature coefficient for the consistency of this 'plastic' product, which necessarily needs to be stored under refrigeration in plants or in homes.

Several empirical instruments viz. cone penetrometer, sectiometer, extrusion devices such as FIRA - NIRD extruder etc. have been used for obtaining the subjective measurements that would correlate with the sensory assessment of spreadability of butter. The most common parameter that is sought to be measured by these methods is hardness of the product. Other less important texture measurements made on butter include its stickiness or oiliness and brittleness but not all instruments give this information. Most popular in Germany, the sectiometer is now available as a highly sophisticated microprocessor controlled instrument (Buttomat). The cone penetrometer has frequently been used for routine purposes in New Zealand, Australia and UK. extruder thrust (from the NIRD instrument) has been found to correlate very well with sensory prepareability of butter. Recently the Instron back extension test has been employed to compare the consistency of commercial butter made by different processes.

Attempts have also been made since early sixties to measure basic rheological properties of butter such as creep behavior, dynamic moduli etc. Extrusion and rotation viscometers have been employed to determine the yield point and plastic viscosity. Recently, the lubricated squeezing flow rheometry has been applied to butter.
Beside temperature, compositional and other related factors such as moisture, SNF, salting, ripening etc. have been found to influence the rheological behaviour of butter. The solid fat content seems to be the major determinant of butter rheology as also the state of fat crystals. Work softening, referring to the softening effect of working is important to butter handling. Rheological measurements such as yield stress have been used to study this phenomenon.

The processing parameters in conjunction with the physical properties or milk fat in butter govern the structure of butter (believed to be a dispersion of fat globules and aqueous phase in a continuous phase of liquid fat) which is responsible for the typical rheological behaviour of the product.

4. RHEOLOGY OF TRADITIONAL MILK PRODUCTS

Industrial production of traditional milk products is yet to come of age in this country. Although studies have been conducted on several technological and quality aspects of these products during the past four decades, their rheological behaviour has aroused little research interest in the past. Occasionally, certain empirical instruments such as cone penetrometer or similar contraptions for compression studies have been used. Process developments studies in respect of rasogolla have benefitted by the use of cone penetrometer for determining the product’s firmness. The penetrometer has been used for certain khoa- and chhana based sweets such as burfi, sandesh etc.

In the first ever attempt to study the viscoelasticity of a traditional product like paneer at PAU, Ludhiana the relaxation times have been worked out employing compression in an Instron machine. A mechanical model has also been proposed to describe the viscoelastic behaviour of paneer. Khoa may be a solid or semi-solid product depending on its type and/or moisture content. However, at high temperature such as those encountered during its manufacture this product is essentially a pseudoplastic fluid, the relevant power law parameters being a function of total solids.

The viscosity of khoa at 30°C as measured in Hoenppler consistometer has been found to range from \(2.0 \times 10^4\) to \(7.6 \times 10^5\) poise with the product TS ranging from 56 to 72 %. Texture profile parameters of khoa determined as a function of composition have been studied and TPA hardness has been found to exhibit a significant correlation with the corresponding sensory attribute of the product.

In recent times investigations have been carried out at this Institute with a view to generating the information on rheology of various indigenous products other than khoa viz., chhana and chhana-based sweets such as rasogolla, and sandesh, paneer, and khoa - based sweets such as kalakand, gulabjamun etc. Temperature and test conditions during parallel plate compression for TPA of these products are major factors affecting the measurements. Further, in most cases, the TPA hardness has been observed to be the single most important parameter.
5. CONCLUSION

Solid dairy products such as cheese, butter and many traditional products including milk sweets are composite products. These viscoelastic products rheological behaviour is greatly influenced by composition and test conditions. Empirical methods have been gainfully used in the past for their behavioural characterization, but in recent times modern instruments have made considerable contribution in this regard. Instrumental texture profile analysis seems quite useful in product texture understanding, but has its own limitations. Some work has already been directed towards understanding the basic rheological properties of these products, but much more efforts need to be made especially with regard to the traditional dairy products.

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RO​LE OF FOOD FLOW PROPERTIES IN PROCESS EQUIPMENT DESIGN

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1. INTRODUCTION

The term rheology has been defined as "a science devoted to the study of deformation and flow". Rheology encompasses the area of fluid flow, which is important to many segments of the processed food industry. Many of the rheological concepts can be utilized in the description of: (a) suspension flow, (b) the flow of granular products or powders, and (c) solid food products. It should not be assumed that the theories developed for other materials will apply directly and ideally to food products. Several factors tend to make the circumstances more complex. Factors such as temperature, humidity, and chemical or microbiological reactions which occur in food products may considerably influence the rheological properties of the product. These complexities lead to the more frequent use of experimentally measured parameters and the development of concepts which are not utilized in other fields. The basic theories and concepts that have been developed for non-food materials must be analyzed, however, so that they can be applied in the development of the optimum approaches to be utilized in food-processing situations.

2. WHY DOES ONE CARE HOW FLUIDS FLOW?

Many food products exist as a liquid at some point in their development and almost all food products involve liquids in their preparation or processing. It becomes important, therefore, that the basic concepts of fluid mechanics are understood by the food processor. In general, the handling of fluid products involve the movement of fluids such as apple sauce, apple juice, tomato ketchup, milk, molasses, etc. through pipes, ducts, or channels. Fluid motion requires energy inputs to compensate for flow losses. Thus, the flow properties greatly influence the energy required in pumping, sizing of piping for transporting the material and design of heat exchangers.

3. CHARACTERISTICS OF FLUID FLOW

The manner in which a fluid flows through a given system depends on a number of parameters including: fluid viscosity, fluid density, fluid velocity, size and shape of the pipe or duct, and the roughness of the surfaces in contact with the fluid. The flow may be broadly categorized as either laminar flow or turbulent flow.

LAMINAR FLOW is characterized by the fluid particles sliding smoothly along parallel stream lines (Visualize the flow of warm honey). TURBULENT FLOW is characterized by fluid particles moving in a random, tumbling, churning motion. (Visualize the flow of water in a very steep canyon stream). If one considers the flow of fluid through a
pipe, it may be observed that the velocity of the fluid is the greatest at the centre and decreases toward the pipe wall with the velocity of the fluid particles at the wall being zero. This is true for both laminar and turbulent flow as depicted in Fig.1.

![Laminar velocity profile Turbulent velocity profile](image)

**Fig. 1. Pipe flow velocity profiles**

### 3.1 Viscosity

Viscosity is a measure of resistance of fluids to shear. Consider two flat plates separated a short distance $y$ by a layer of fluid as indicated in Fig.2. Assume that the top plate is forced to move with velocity $v$ relative to the bottom plate. The force $F$ per unit area $A$ required to give the top plate this velocity is proportional to the change in fluid velocity $v$ per change in distance $y$:

$$\frac{F}{A} \propto \frac{v}{A} \quad \text{or} \quad F = \mu \left(-\frac{dv}{dy}\right) \quad \text{..........(1)}$$

The proportionality factor $\mu$ is called the viscosity of the fluid having units of N.s/m$^2$ in the SI system. Tabulated values of viscosity are often given in centipoise, where

1 centipoise = 0.001 N.s/m$^2$ = 1 g/m.s

![Viscosity](image)

**Fig. 2. Visualisation of viscosity**

Fluids are described as Newtonian or non-Newtonian based on the behaviour of viscosity. Equation (1) states that viscosity $\mu$ is proportionality factor relating shear stress(F/A) and shearing rate (dv/dy). It is relatively easy to predict the fluid flow characteristics of a Newtonian fluid because the viscosity has the same value when the fluid moves very rapidly as it does when the fluid moves very slowly. For Newtonian fluids, viscosity can be tabulated as a fluid property that varies only with temperature. To predict the fluid flow characteristics of a non-Newtonian fluid usually involves finding an equation that approximates the shear stress to shear strain relationship so that the viscosity data for a non-Newtonian fluid is more complicate since it varies with both temperature and shearing rate.

All gases and a great many common liquids behave as Newtonian fluids. Non-Newtonian liquids are usually solutions or slurries that contain substances composed of long chain molecules. Unfortunately, most foods contain long chain molecules and would exhibit non-Newtonian behaviour. Nevertheless, many liquid food products can be modelled as Newtonian fluids by using an appropriate viscosity and recognizing that a significant error could occur. For many non-Newtonian fluids the Herschel-Bulkley model discussed in an earlier lecture would serve as a general rheological model.
3.2 The Reynolds number

Osborne Reynolds developed a mathematical relationship to predict whether the flow will be laminar or turbulent. He found that there were four critical parameters: pipe diameter (D), average fluid velocity (v), mass density (ρ) and fluid viscosity (μ). These are correlated into a dimension less number called the Reynolds number (Re):

\[ Re = \frac{Dvρ}{μ} \] ........................(2)

It has been found that for pipe flow, if Re < 2300 the flow will usually be laminar. If Re > 2300 the flow will generally be turbulent. The value of Re at which the transition from laminar to turbulent flow exists is called the critical Reynolds number.

For non-Newtonian fluids the generalized Reynolds number is written as:

\[ (Re)_G = \frac{D^n v^n - n}{m.8^{n-1}} \] ........................(3)

3.3 Friction

One of the primary factors to be included in the application of rheological data to the computation of fluid flow problems in food processing operations is friction. Friction influences the flow properties of a food product in several ways, including the flow of one layer of product another, the flow of the product over a wall surface, and the flow of the product through some change in the transport system. In most applications, friction is defined or explained as a force which opposes the flow of a fluid in the system. This leads to the following expression for a unit mass of fluid:

\[ F = A (KE) f \] ........................(4)

in which the force is defined as the product of area (A), kinetic energy (KE) and a friction factor (f). In this case, the characteristic area is the area on which the friction is occurring. For example, the friction or force opposing flow occurring on a wall would have an area equal to the wall surface area. The friction factor (f) is a dimension less quantity and has been used extensively in the development of charts which allow the computation of a friction factor as a function of Reynolds number. Probably the best known of these charts was developed by Moody for Newtonian fluids; it indicates the importance of surface roughness when the flow in the tube is turbulent.

3.4 Friction losses in pipe flow

A fluid flowing through a pipe always experiences a loss of pressure due to friction \( h_f \) that depends on the length of the pipe (L), the diameter of the pipe (D), the fluid velocity (\( \bar{v} \)), and pipe roughness (e). These parameters have been correlated into a formula called Darcy's formula, expressing this loss of flow energy as

\[ h_f = \frac{fL}{D} \cdot \frac{\bar{v}^2}{2g_e} \] ........................(5)

The coefficient of friction (f) depends on the Reynolds number and pipe roughness.

The accepted values of absolute roughness e for various types of new pipes can be found in standard tables. A pipe wall projection the size of a grain of sand would have little
effect on the flow through a large diameter water main but could be very significant on flow through a small tube. Therefore, the relative roughness is the important criterion. For determining the power requirement in pumping a fluid, $h_f$ plays the most significant role.

4. FLOW PROPERTIES IN HEAT EXCHANGER DESIGN

Heating and cooling of food products are probably the most frequently occurring processes in the food processing plant. Only a small percentage of processed foods do not receive some type of heat treatment or are not cooled at some point between the time of entering the food processing plant and arriving at the point of consumption. As heat transfer is the unit operation involved in both heating and cooling, it must receive considerable attention when designing processes for processing plant.

The theoretical and empirical relationships utilized in the design of heat processes assume knowledge of the thermal and flow properties of the materials being utilized. Unfortunately this information on food products is not always readily available. Further what complicates the use of the most readily available relationships in heat transfer for food products is their non-Newtonian flow characteristics. There is an increasing amount of literature accumulating on heat transfer to non-Newtonian fluids during laminar and turbulent flow, and the application of this information to heat transfer in food products should be extremely useful.

4.1 Convective heat transfer

Heat transfer is defined as the transmission of energy from one region to another by means of a temperature gradient which exists between the two regions. There are three recognized modes of heat transfer: conduction, radiation and convection. Though convection does not conform entirely to the strict definition of heat transfer, it has been accepted as an important heat transfer mode. In this particular mode, energy is transported by a combination of heat conduction, energy storage and mixing action. An example of convection is the transfer of heat to a product in a tubular heat exchanger where heat is transferred from the wall to the fluid by conduction, energy storage and mixing action of the fluid product.

Heat transfer in a fluid system will normally occur by convection. Since the transfer of heat by convection is due to the mixing action within the fluid, the rate of heat flow from a surface to the fluid will depend on the fluid flow properties as well as the thermal properties of the fluid. Fig. 3 illustrates the type of temperature gradient that will exist when a warm wall surface is exposed to a fluid. The region near the wall within which the temperature changes from the wall temperature ($T_w$) to the free stream temperature ($T_\infty$) is defined as the thermal boundary layer in much the same way as the hydrodynamic boundary layer in which the velocity changes from wall to the free stream. The conditions illustrated can exist under both free convection and forced convection. The basic equation which describes heat transfer by convection is:

$$q = h_v A (T_w - T_\infty) \quad \text{(6)}$$

where $h_v$ is the convection heat-transfer coefficient, which will depend on the fluid flow characteristics and thermal properties of the fluid.
Most of the available information which leads to the evaluation of the convective heat-transfer coefficient is in the form of empirical relationships. These relationships may be derived from a theoretical basis, or they may be based on dimensional analysis.

4.1.1 Forced convection

In forced convection, the fluid flow patterns around the heated surface are determined by an external force such as a pump or a fan. Dimensional analysis reveals the relationship between three dimensionless groups as shown in the following expression:

\[ \text{Nu} = f (\text{Re}, \text{Pr}) \]............(7)

where

\[ N_u = \frac{k_c L}{k_f} \]............(8) \hspace{1cm} \[ P_r = \frac{C_p \mu}{k_f} \]............(9)

The dimensionless groups in equation (7) are the Nusselt number (Nu), the Reynolds number (Re), and the Prandtl number (Pr). The Nusselt number, defined in equation (8), is directly dependent on the convective heat-transfer coefficient (h_c), some characteristic dimension (L) and the thermal conductivity of fluid (k_f). The third dimensionless group is the Prandtl number which is directly dependent on thermal and physical properties of the fluid as shown in equation (9).

In designing heat transfer equipment it is important for an engineer to estimate the Convective heat transfer coefficient. The following discussion provides information to estimate h_c values for different geometries.

The classic example of the theoretical basis for the relationship given by equation (7) is heat transfer from a flat plate to a fluid during laminar flow. In this particular situation, the continuity equation, the momentum equation and the energy equation are combined and solved to give an exact solution of the following form:

\[ \text{Nu} = 0.664 R_e^{1/2} P_r^{1/3} \]............(10)

The most widely used expressions in the design of equipment for food processing are those which allow the evaluation of heat-transfer coefficients in tubular geometries, primarily tubular heat exchangers used in various processes. As might be expected, most of the available expressions represent examples of the empirical relationships available and, in addition, represent types which appear to have considerable use in the design of processing equipment for foods.

One of the obvious problems when evaluating convective heat-transfer coefficients for tubular geometries is the selection of the temperatures to be used in equation (6) and the
temperature at which the properties of the fluid will be evaluated. The so-called free-stream temperature \((T_\infty)\) will vary from the entrance to the outlet of a tube in which convective heat transfer is occurring. The actual rise in temperature is described by the expression:

\[
Q = \dot{m} C_p \Delta T_b \quad \cdots \quad (11)
\]

Where \(\Delta T_b\) is the change in bulk fluid temperature between entrance and exit of the tube. The bulk temperature \((T_b)\) is the average temperature of the fluid at the given cross-section in the tube. The convective heat-transfer coefficient will then be defined by a revised form of equation (6) as follows:

\[
h_{cl} = \frac{q}{A(T_e - T_b)_{in}} \quad \cdots \quad (12)
\]

where the convective heat-transfer coefficient is based on the log mean temperature difference between the surface and bulk temperature of the fluid defined as:

\[
(T_e - T_b) = \frac{(T_e - T_{b1}) - (T_e - T_{b2})}{\ln \left(\frac{T_e - T_{b1}}{T_e - T_{b2}}\right)} \quad \cdots \quad (13)
\]

assuming that the tube has a constant surface temperature in the axial direction.

Most empirical expressions thus derived to allow evaluation of the convective heat transfer vary depending on the flow characteristics of the tube and in some cases on whether the fluid is being heated or cooled in the tube.

4.1.2 Free convection

During free or natural convection, fluid flow is not induced by external forces and the motion within the fluid is brought about by the influence of temperature on fluid density and the development of a buoyant force. Under these conditions, the fluid motion is described in terms of the Grashof number \((Gr)\), which is defined in the following way:

\[
Gr = \frac{\rho^2 g \beta X^3 \Delta T}{\mu^2} \quad \cdots \quad (14)
\]

where \(X\) is the characteristic dimension of the body involved in the natural or free convection, \(\beta\) is the coefficient of expansion of the fluid being heated, and \(\Delta T\) is the temperature gradient between the surface and the fluid. Empirical relationships involving free convection are of the following form:

\[
N_u = K (Gr P_r)^a \quad \cdots \quad (15)
\]

where the Nusselt number describes an average convective heat-transfer coefficient for the surface and the constants \((K\) and \(a\)) vary with the geometry and orientation of the surface.

One general statement which must be made concerning all the relationships presented for evaluation of convective heat-transfer coefficients is that the expressions have been developed for Newtonian fluids. Since the flow characteristics of food products may considerably deviate from Newtonian flow, the error involved in the use of these expressions for non-Newtonian fluids may be significant. Some efforts should be made, however, to utilize expressions containing generalised Reynolds and Prandtl numbers to describe and incorporate the non-Newtonian state existing in many food products.
VIII. STRUCTURE OF DAIRY PRODUCTS
SEM TECHNIQUES FOR THE STUDY OF MICROSTRUCTURE OF DAIRY PRODUCTS

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1. INTRODUCTION

Electron microscopy is primarily useful because of its high resolving power compared to other systems employing light as the illuminant. Scanning electron microscopy (SEM) and transmissions electron microscopy (TEM) are the two major techniques employing electron beams for microstructure analysis. The present discussion will largely relate to SEM. SEM basically provides surface topology or 3-D information.

Milk products form a large group of foods based on milk protein and fat. These range from products with a high water content such as fluid milk to dry products milk powders and from products of high fat content (butter) to low fat content (skim milk curd, yoghurt etc.) Some products are consumed in the frozen state (ice cream and frozen yoghurt). When microstructure of dairy products is studied by EM, the composition of the product is always taken into consideration prior to selection of the technique. However, a number of electron microscopy techniques are available for different dairy foods. Microstructure is precisely the study of individual components of milk such as casein micelles and fat globules and the changes which these components undergo either alone or by interaction with each other or with added ingredients like stabilizer emulsifiers, thickeners, starter cultures etc. It is recognized to control some of the physical properties like viscosity, firmness, elasticity and syneresis in various products.

2. SEM OF DRY SPECIMENS

Products which are marketed in dry forms (powders of milk, whey, butter milk and other powders) can be studied conveniently. Preparation of such samples is simple and consist of mounting powder particles on the metal stubs and coated with gold on gold-palladium alloy. Double sticky tape is easier to use than liquid cement particularly when powder particles are porous in nature. After mounting excess particles are removed from the tape by stream of air or nitrogen or are shaken off in order to avoid overlapping and changing effect. Painting of tape edges with conductive silver cement provides an un-interrupted conductive surface between sample and metal stub after coating with gold by sputter coater at around 200 A°. SEM provides observation of both external appearance of powder particles as well as their internal microstructure in fractured particles. Milk powders are generally hygroscopic in nature and therefore is required to process under controlled low humidity. Different powder product show a characteristic morphology in terms of external and internal details. These features, change if the processing however parameters are modified.
3. SEM OF WATER-CONTAINING MILK PRODUCTS

3.1. Drying of samples

More steps are involved to dry the milk products as compared to dry powders. Since drying may alter the original microstructure of the products, the major protein components is first fixed. Fixation in EM is defined as the selective preservation of biological systems in their natural state. These fixations act upon macro molecules to substitute other bonds which stabilizes structures and will resist any further solubilization during sample processing such as dehydration and embedding etc.

Glutaraldehyde is the most commonly employed fixative. The concentration as well as the duration of fixation may vary depending upon the type of material. Drying of samples are mostly accomplished by freeze-drying or critical point drying (CPD). In the former case, sample are frozen quickly below -70°C to avoid ice crystal formation and thus damage to protein microstructure, and the ice is sublimed in vacuum leaving to samples dry.

Critical point drying is another technique suitable for drying most milk products which have been previously fixed, dehydrated in alcohol or acetone. The technique is based on conversion of liquid CO₂ in which the dehydrated samples in immersed in a pressure vessel and with which it is gradually impregnated into the gaseous form by increasing the temperature above critical point. Above this temperature, CO₂ exist only as gas irrespective of the pressure applied. The specimen thus does not pass through any 'phase boundary' as is common with all other techniques. Although it is suitable for most milk products based on protein it should not be applied to products which contain gelatinised starch.

In other cases, where the sample is hard it can be air dried following fixation and alcohol acetone dehydration. It may be remembered that high fat products such as cheese for SEM in the dry form are usually defatted otherwise it would obscure the protein matrix and also cause charging artefacts. Defatting may be attained through the treatment of acetone, chloroform or mixture of petroleum and di-ethyl ether.

3.2 Mounting of samples

After the samples are dried by the above procedures, these are the fractured before mounting on the stubs. Fracturing is done by hand under a stereo microscope. The tip of sharp blade is briefly pressed into the edge of the sample block and particle is broken exposing the internal structures. Specimen fractured fragments are mounted on the metal stub using conductive silver paint, then coated with gold and finally examined under the SEM.

4. SEM OF FROZEN SPECIMENS

Milk products which cannot be dried without artefactual changes such as cream, butter etc. may be examined with SEM while frozen. No chemical fixation of the specimen is required because the specimen is cryofixed. A cold stage mounting inside the electron microscope which keeps the specimen at a low temperature (-100 to -70°C) is pre requisite for this technique. Although preliminary viewing may be undertaken even without the cold
storage provided that the specimen is pre cooled with liquid nitrogen before insertion in the electron microscope and quickly received before its temperature rises too high. Otherwise the specimen is freeze-fractured inside the microscope and examined directly or after coating with gold. A number of modifications have been made by different workers.

5. SEM OF REPLICATED SPECIMENS

In this, the great difficulty in drying of high fat milk product for conventional SEM without introducing artefacts in their structure and the need to use a cold stage attachments in EM to examine at a low temperature have been by passed. The technique in which freeze-fractured specimens is coated with gold, the gold coating is separated from the specimen in the form of a 'replica' and the replica is examined by conventional SEM at ambient temperature. A number of hypothesis have been made in the procedure by various workers.

6. MICROSTRUCTURE OF SELECTED DAIRY PRODUCTS

6.1 Yoghurt

The casein micelle which forms the building block of protein microstructure is a macromolecular assembly of as αs-β- and κ caseins held together by an amorphous calcium phosphate citrate complex and occur as a separate entity in fresh milk. The particles are distinguished by their spherical shape, ranging in diameter from 30 or less to 300 nm, with a molecular weight from 10 to 3280 millions. Yoghurt is a fermented dairy product using combination of lactic cultures with higher total solids. The protein matrix of yoghurt is composed of casein micelles which are fused together and form chains and clusters due to lowering of pH by lactic acid. The protein matrix is continuous in the set-style yoghurt, whereas is disrupted in the stirred yoghurt. The presence of lactic bacteria in yoghurt can be observed. Bacterial colonies form pockets in the protein matrix. Pre heating of milk at 90°C result in firm coagulum. Heating denatures whey protein (α-lactalbumin & β-lactoglobulin) and leads to the formation of a complex between β-lactoglobulin and κ-casein on the casein micelle surface.

Similarly, microstructure of modified yoghurt and other types of curds could be studied based on variation of protein matrix.

6.2 Cheese

Cheese is one of the most important dairy products that have attracted the attention of scientists for the study of microstructure. Among cheeses, Cheddar cheese probably has been studied to the greatest extent.

Most cheeses are made from whole milk and coagulation is achieved by a combined action of starter lactic bacteria and a proteolytic enzyme, rennet. Casein micelles in milk aggregate during cheese making and fat globules are entrapped in the coagulum. For the study of microstructure of the curd, it is necessary to remove fat by treating with chloroform or other solvent. The cheese curd develops by chaining and clustering of casein micelles which gradually form a 3-dimensional net-work. Different pattern of matrices can be seen in various cheeses.
6. 3 Milk powders

Milk is generally dried through spray drying and roller drying. Skim milk powder particles are generally round with different surface structures. Some particles show smooth but most of them appear severely wrinkled with deep surface folds. A large proportion of particles give 'apple like structure'. The fractured powder particles reveal the internal structure having large vacuole entrapping a number of smaller particles. In whole milk powder (spray dried) the body of the particles are generally porous. High porosity was usually associated with the occurrence of cracks and capillaries in the particles. The spray dried milk powder particles range widely in diameter between several micrometer to several tens of micrometer.

The particles of roller dried milk powder are flakes in which casein micelles are aggregated in clusters. Similarly, the instant milk powder particles show rough surfaces covered with relatively large lactose crystals.

7. CONCLUSION

Electron microscopy (EM) has become an invaluable tool with which the microstructure of foods can be studied especially in relation to the product texture. However, the interpretation of microstructure as revealed by EM is very crucial for any product. It is often necessary to examine the sample by alternative method before any meaningful conclusion can be drawn.

SELECTED REFERENCES


Johari, O. and De Ne (1972) Handling, mounting and examination of particles for SEM. Scanning Electronmicro. 1: 249-256.


1. INTRODUCTION

Characterization of various food products on the basis of their rheology and microstructure forms the backbone of the scientific approach to product/process development and of quality assurance in modern industrial practices. The current trends round the globe favour such studies to facilitate product description/specification for promoting process control and for international trade. Furthermore, the interest of researchers and manufacturers in the texture and structure of various milk products has been growing, as it is recognized that there are definite correlations between the structure and other physical properties of the products. The physical manifestation of food materials is due to its chemical make-up and a microstructural study may yield the true insight into their textual attributes. Evaluation of geometrical properties of foods are important for their characterization; these properties refer to the arrangement of constituents of food including the size, shape and orientation of the particles. Electron microscopy is useful to study surface topology and to develop correlation between the structure of various food material and then physico-chemical properties.

At a juncture when the need for modernising the manufacturing and marketing of traditional milk products is being emphasized in India, such rheological and electron microscopic studies would be sine qua non to obtain much needed information for product/process development. Further, the Bureau of Indian Standards (BIS) is actively considering the views of defining/describing the food products based on their structure. It is worthwhile to mention here that BIS has already made a headway in this direction in respect of some of the food products such as roasted chicory and coffee powder. In the past few years, some work has been directed to study the rheology of selected indigenous dairy products such as paneer, khoa, rasogolla and sandesh. However, the area encompassing the microstructural studies has not received much scientific inputs so far in our country. Since rheology is determined by microstructure, studies on the latter would also help us to establish the relationship between them. Keeping this in view, an attempt is made in this lecture to put forth the textural and structural aspects of some of the heat and acid coagulated indigenous milk products such as paneer, chhana and rasogolla.
2. PANEER

2.1 Textural properties of paneer

The data on the objective textural properties of raw and fried and cooked paneers made from cow and buffalo milks has been shown in Table 1. It is evident from the table that primary parameters such as hardness and springiness differed significantly between cow and buffalo milk paneers. Cohesiveness, on the other hand, did not differ much between these two paneers. Since secondary parameters such as gumminess and chewiness are dependent on primary parameters, buffalo milk paneer revealed considerably higher values for gumminess and chewiness compared to those recorded for cow milk paneer (Desai, 1988).

Table 1. Instron texture profile analysis of paneer made from cow and buffalo milks

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Cow milk paneer</th>
<th>Buffalo milk paneer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Raw</td>
<td>Fried and cooked</td>
</tr>
<tr>
<td>Hardness, mN</td>
<td>25.59</td>
<td>8.66</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>0.67</td>
<td>0.70</td>
</tr>
<tr>
<td>Springiness, mm</td>
<td>7.30</td>
<td>9.38</td>
</tr>
<tr>
<td>Gumminess, mN</td>
<td>17.04</td>
<td>6.12</td>
</tr>
<tr>
<td>Chewiness, mN.mm</td>
<td>131.27</td>
<td>54.27</td>
</tr>
</tbody>
</table>

Adapted from Desai (1988)

Frying in oil and cooking in salt water remarkably reduced the hardness, gumminess and chewiness and increased the cohesiveness and springiness of both the paneer.

2.2 Microstructure of paneer

Scanning electron microscopy (SEM) reveals that in the raw state, both cow and buffalo paneers possessed uniformly aggregated protein particles and fat globules are evenly distributed in the protein net work (Kalab et al, 1988). Transmission Electron microscopy (TEM) confirmed the existence of granular structure in paneer and also exhibited the internal structure of the protein particles. Raw cow milk paneer has uniformly packed small protein particles and resembled cottage cheese (Glaser et al., 1979), while in raw buffalo milk paneer protein particles were more densely packed and fused. Core-and-lining structure which is characteristic of curds obtained by coagulation of hot milk at pH 5.5, is well developed in both the paneers. The development of core-and-lining structure is influenced by the temperature and pH of coagulation (Harvark and Kalab, 1981).

Frying of paneer in oil severely changed its structure. SEM shows that compaction suppressed the smooth granularity of the protein matrix in cow milk paneer. The granularity totally vanished in the buffalo milk paneer. The compaction is more clearly evident in TEM ultratgraphs. The compaction also caused the fat globules to acquire sharp and pointed outlines unlike their globular shape in raw paneer. Cooking of fried paneer in salt water restored both the granular structure and core-and-lining structure of the protein bodies. This restoration was more in case of cow milk paneer as compared to buffalo milk paneer.
3. CHHANA

3.1 Textural properties of chhana

Instron textural attributes of chhana made from cow and buffalo milks are given in table 2. It is evident that all the textural values were less for cow milk chhana compared to that of buffalo milk chhana. The secondary parameters such as gumminess and chewiness for buffalo milk chhana were more than two times to those values for cow milk chhana. However there was not much difference between cow milk and buffalo milk chhana as far as the adhesiveness was concerned (Adhikari, 1992).

Table 2. Instron texture profile properties of chhana

<table>
<thead>
<tr>
<th>Textural attributes</th>
<th>Cow milk chhana</th>
<th>Buffalo milk chhana</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (mN)</td>
<td>11.60</td>
<td>19.50</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>0.59</td>
<td>0.67</td>
</tr>
<tr>
<td>Springiness (mm)</td>
<td>3.60</td>
<td>5.00</td>
</tr>
<tr>
<td>Gumminess (mN)</td>
<td>6.48</td>
<td>13.06</td>
</tr>
<tr>
<td>Chewiness (mN.mm)</td>
<td>24.64</td>
<td>65.32</td>
</tr>
<tr>
<td>Adhesiveness (mN)</td>
<td>0.35</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Adapted from Adhikari (1992)

3.2 Microstructure of chhana

SEM of a defatted cow milk chhana reveals conglomerated and compact protein material (casein whey protein complexes with numerous small uniformly distributed pores of irregular shape. The protein particles coalesced and fused densely during coagulation and lost their natural identity of subunit sizes as seen in milk. The coalesced, smooth protein bodies were joined with thick bridges (Adhikari et al, 1992). SEM of defatted buffalo milk chhana also shows a similar compact, coalesced protein net work with numerous globular and irregular voids throughout the matrix, but slightly more uneven as compared to cow milk chhana. The globular void spaces indicate that the casein-whey protein complexes are closely interspersed with numerous fat globules due to the usage of whole milk. Cow and buffalo milk chhana has been shown to contain fat globules embedded in coalesced casein micelles with some whey-filled spaces at the edge. The agglomerated large protein particles form continuous thick strands joined together forming somewhat uneven matrix with numerous void spaces in between. The fat globules strongly cemented in these thick protein strands. The overall structure is more or less similar to that of cream cheese (Kalab and Modler, 1985) or Gibna Baida (Sudanese cheese) (Ali & Robinson, 1990), in which the fat globules were found cemented together with the coalesced protein particles as seen in chhana.
4. RASOGOLLA

4.1 Texture profile analysis of rasogolla

Instron textural attributes of rasogolla are shown in Table 3. It is clear from the table that cow milk rasogolla has significantly lower hardness, springiness, gumminess and chewiness than that of buffalo milk rasogolla. The hardness of buffalo milk rasogolla in 2-3 times higher than that of cow milk rasogolla. Springiness of buffalo milk rasogolla (6.4 mm) is markedly higher than that of cow milk rasogolla (4.8 mm). Cohesiveness varied from 0.61 (cow milk rasogolla) - 0.70 (buffalo milk rasogolla). As the consequence of higher hardness and springiness in buffalo milk rasogolla, their gumminess and chewiness values also increased remarkably than that of cow milk rasogollas. No adhesive force, however, has been recorded for either of the rasogollas.

Table 3. Instron texture profile of rasogolla

<table>
<thead>
<tr>
<th>Textural attributes</th>
<th>Cow milk rasogolla</th>
<th>Buffalo milk rasogolla</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (mN)</td>
<td>5.85</td>
<td>16.82</td>
</tr>
<tr>
<td>Cohesiveness</td>
<td>0.61</td>
<td>0.70</td>
</tr>
<tr>
<td>Springiness (mm)</td>
<td>4.80</td>
<td>6.40</td>
</tr>
<tr>
<td>Gumminess</td>
<td>3.57</td>
<td>12.17</td>
</tr>
<tr>
<td>Chewiness (mN. mm)</td>
<td>17.15</td>
<td>77.88</td>
</tr>
</tbody>
</table>

Adapted from Adhikari (1992)

4.2 Microstructure of rasogolla

Cooking of chhana in sugar syrup (for 15 min.) severely altered the structure of both the fat and the protein phases. The microstructure of rasogolla exhibits a distinctly different protein net work from chhana at low magnification, a ragged and cracked protein matrix can be seen obscured with fat and several void spaces interspersed throughout. Higher magnification revealed that the fat globules are shrunk and ruptured, finally coalescing to a large mass and losing their natural identity as globular with a smooth surface as is found in chhana.

A defatted rasogolla sample showed a ragged, porous, loose protein matrix with a folded thread-like structure. The clumped protein particles formed a corrugated edge around the void space. Higher magnification showed that the folded protein particles were interlinked with thick protein bridges forming a core type structure with numerous voids.

Similarly, the fat globule structure in buffalo milk rasogolla revealed drastic shrinkage of the fat globule membrane and globules partly detached from the protein bodies. The defatted protein matrix in buffalo milk rasogolla was more compact and ragged with lesser voids as compared to cow milk rasogolla.
4.3 Interrelationships between texture and microstructure of chhana and rasogolla

The denser protein network present in chhana reduced the mean free path of the coalesced casein micelles which reduced the capacity of the fat and protein phases to move in relation to each other. Where as in rasogolla the large voids between the coalesced protein gave the free access of the protein bodies to move freely during the instron testing, resulting its lower hardness but higher springiness. This higher springiness in rasogollas may be attributed to its loose, porous and ragged protein matrix.

REFERENCES


IX. COLOUR MEASUREMENT
TRISTIMULUS COLOUR MEASUREMENT IN FOODS

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1. INTRODUCTION

Colour is an extremely important sensory attribute of foods that in many cases is the first criterion to be perceived by the consumer. The human eye is a very sensitive organ - it can detect up to 10,00,00,000 different colours. Colour is not just a physical thing, determined by certain surface characteristics of the object you are looking at - it is psycho-physical phenomenon. It is not only a question of the light signals that come into the eye, but the way in which the eye and brain together interpret them.

It is well known that the repeated recognition of a particular brand of food commodity largely depends on its typical colour. Thus, in the food industry the assessment of the colour of foods and its components has become an integral part of total quality control. Colour of a product is to be kept uniform and constant from batch to batch. Usually the colour is observed visually, which is influenced by the testing conditions. Furthermore, the final outcome depends largely on the observer's ability to differentiate colours and hue. In contrast to this subjective approach, instrumental colour measurement offers the advantage of objectiveness and a well-defined measuring scale. Therefore, results thereby obtained fulfill the requirement of reproducibility and comparability.

Reliable instrumental methodologies for the objective assessment of colour have been developed and have found widespread use in many food sectors. For instance, instrumental assessment of the colour of meat and meat products (Stolle and Paulick, 1990) egg yolk (McCready et al., 1973), fruits and vegetables (Kader and Morris, 1978; Wainwright and Hughes, 1989), sweets and chocolate (Kneifel et al., 1990) and coffee (Francis and Clydesdale, 1975) has been described. Several reports concerning milk and dairy products can also be found in the literature (Bosset and Blanc, 1978; Bosset et al., 1979, 1986; Giangiacomo and Messina, 1988, 1989; Kneifel et al., 1992 a,b; Mukherjee, 1996).

2. THE PRINCIPLE OF TRISTIMULUS COLORIMETRY

A colorimeter is an instrument to reproduce optically and electronically the physiological sensation of the human eye. A colorimeter measures colour as such and is not to be confused with the earlier use of the word colorimeter used in chemical analysis.

The design of a modern colorimeter can best be understood by an analogy to the way the human eye sees colour. We have two anatomically distinct types of receptors in the human eye—the rods and cones. The rods are concerned with black and white vision in dim
light and have no colour function. There are three types of cones in the human retina: one sensitive to red, one to blue and the other to green. The human eye receives light reflected from an object to the retina and a signal from each type of cone is sent to the brain. The brain interprets the signals and assigns a 'colour' to the object.

A simple colorimeter can be designed to duplicate the response of the human eye. If an operator can vary the amount of red, green and blue light reaching the screen, he can match almost any colour. Then the unknown colour can be described by the amount of red, green and blue required to match it (Fig. 1). This principle has been used in several visual colorimeters to define the fundamental colour solid. The colorimeter itself is too crude for everyday use but the data can be used to define a much more appropriate colour solid. Every realisable colour will have three coordinates which locate the point within the colour solid. When one says 'measure the colour', one is asking for the three coordinates which locate a point in space. Such methodology is known as tristimulus colorimetry.

![Fig 1. A right-angled GRB chromaticity diagram (Maxwell triangle).](image)

3. TRISTIMULUS COLORIMETERS

There are many types of colorimeters available which can be used to measure colour in a number of different mathematical systems. The choice of instrument and colour solids and the interconversions of one system to another may be bewildering to a newcomer but they are all based on the same principle. One system, called the CIE (Commission Internationale d'Eclairage) has been adopted world-wide as the universal system. Its units are X, Y, Z. This system is based on additive colorimetry such that three primary lights are used to match any given colour. Spectrophotometrically, this may be done by obtaining reading over the visible spectrum and thus producing spectral response curve for the test sample and symbolizing this response by R.

The monochromatic light used to obtain the spectral response is a CIE standard source that has a defined spectral curve of its own. The energy elicited at every wave length
Tristimulus colour measurement

of this curve is symbolized by $E$. Thus, the total energy received by the phototube is the product $RE$.

To obtain values analogous to what the eye perceives, this energy function ($RE$) must be multiplied by the functions $X$, $Y$, and $Z$ of the standard observer curve, respectively. The standard observer curve are simply physical simulations of the three primary lights, red, green, and blue which man uses to match each and every colour. Thus, it is possible via the standard observer curve to predict the proportion of red, green and blue which a person would use to match a specific monochromatic energy output. The similarity of such curves for every human being with normal colour vision is the reason why colour may be

![Image](image_url)

Fig. 2. A simple tristimulus colorimeter.

measured more precisely than other sensory attributes such as flavour. This conversion from the energy functions ($RE_x$, $RE_y$, and $RE_z$) in psychophysical functions may be done by integrating between 380 and 750 nm as follows:

$$X = \int_{380}^{750} RE_x \, d\lambda$$

$$Y = \int_{380}^{750} RE_y \, d\lambda$$

$$Z = \int_{380}^{750} RE_z \, d\lambda$$

Colorimetric readings, however, do not have to be calculated from a spectrophotometer nor do they have to be calculated in terms of $X$, $Y$, $Z$. There are many other scales available that can be calculated from the $X$, $Y$ and $Z$ values or that can be measured directly from a tristimulus colorimeter, rather than a spectrophotometer. A tristimulus colorimeter simply modifies the energy from the sample by means of filters which approximate the standard observer curves to produce a final psychophysical function. Thus, the mathematical manipulation is simulated via filters to produce a faster and more inexpensive method of calculating tristimulus values. However, these may not be as accurate as spectrophotometric techniques.
Table 1. Typical colour parameters of different milk products (mean values of at least 3 different replicate samples); L*: dark (0) light (100); a*: green (-), red (+); b*: blue (-), yellow (+)

<table>
<thead>
<tr>
<th>Product type</th>
<th>Fat content (%)</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
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<tr>
<td>Pasteurized milk</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>&lt;0.1</td>
<td>81.7</td>
<td>-4.8</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>3.6</td>
<td>86.1</td>
<td>-2.1</td>
<td>7.8</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>86.2</td>
<td>-1.7</td>
<td>7.5</td>
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</tr>
<tr>
<td>UHT milk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>86.0</td>
<td>-2.0</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>Cream</td>
<td>36.0</td>
<td>88.1</td>
<td>-0.2</td>
<td>8.8</td>
</tr>
<tr>
<td>Coffee cream</td>
<td>10.0</td>
<td>86.9</td>
<td>-0.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Cultured butter milk</td>
<td>0.1</td>
<td>86.5</td>
<td>-2.6</td>
<td>6.9</td>
</tr>
<tr>
<td>Cultured milk</td>
<td>3.6</td>
<td>87.5</td>
<td>-1.5</td>
<td>6.5</td>
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<td>Yogurt (set-style)</td>
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<td></td>
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<tr>
<td>1.0</td>
<td>85.9</td>
<td>-2.5</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>3.6</td>
<td>86.6</td>
<td>-1.9</td>
<td>9.1</td>
<td></td>
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<tr>
<td>Yogurt with fruits</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>apricot</td>
<td>3.2</td>
<td>82.3</td>
<td>1.3</td>
<td>10.7</td>
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<tr>
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<td>3.2</td>
<td>77.0</td>
<td>9.1</td>
<td>4.9</td>
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<tr>
<td>blueberry</td>
<td>3.2</td>
<td>52.9</td>
<td>20.6</td>
<td>-7.3</td>
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<td>raspberry</td>
<td>3.2</td>
<td>67.8</td>
<td>13.1</td>
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<tr>
<td>Yogurt dessert product</td>
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<tr>
<td>vanilla</td>
<td>7.0</td>
<td>83.7</td>
<td>0.9</td>
<td>11.8</td>
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<tr>
<td>coffee</td>
<td>7.0</td>
<td>66.5</td>
<td>5.3</td>
<td>18.7</td>
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<tr>
<td>Fresh soft cheese</td>
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<td></td>
</tr>
<tr>
<td>&lt;1.0</td>
<td>85.7</td>
<td>-0.9</td>
<td>10.4</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>86.1</td>
<td>-0.9</td>
<td>10.4</td>
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<tr>
<td>20.0</td>
<td>85.6</td>
<td>-0.3</td>
<td>10.6</td>
<td></td>
</tr>
<tr>
<td>40.0</td>
<td>85.0</td>
<td>1.3</td>
<td>10.7</td>
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<tr>
<td>Gervais</td>
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<td>85.9</td>
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<td>12.0</td>
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<tr>
<td>Processed cheese</td>
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<td>91.0</td>
<td>3.0</td>
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<td>Camembert (surface)</td>
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<td>95.7</td>
<td>0.1</td>
<td>5.2</td>
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<td>(interior)</td>
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<td>85.6</td>
<td>3.3</td>
<td>26.9</td>
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<tr>
<td>(surface)</td>
<td>60.0</td>
<td>94.6</td>
<td>0.5</td>
<td>5.9</td>
</tr>
<tr>
<td>(interior)</td>
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<td>86.8</td>
<td>3.2</td>
<td>27.7</td>
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<tr>
<td>Brie (surface)</td>
<td>60.0</td>
<td>95.9</td>
<td>0.2</td>
<td>4.1</td>
</tr>
<tr>
<td>(interior)</td>
<td></td>
<td>90.2</td>
<td>2.7</td>
<td>26.5</td>
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<tr>
<td>Feta cheese</td>
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<td>93.5</td>
<td>-1.1</td>
<td>11.0</td>
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<td>50.0</td>
<td>92.8</td>
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<td>77.2</td>
<td>3.1</td>
<td>28.8</td>
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<td>4.2</td>
<td>32.2</td>
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<td>82.6</td>
<td>3.6</td>
<td>27.1</td>
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<tr>
<td>Swiss type cheese</td>
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<td>72.7</td>
<td>0.6</td>
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<td>Full-cream milk powder</td>
<td>25.0</td>
<td>95.6</td>
<td>-3.6</td>
<td>19.8</td>
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<tr>
<td>Skimmed milk powder</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>(New Zealand origin)</td>
<td>1.0</td>
<td>93.0</td>
<td>-2.2</td>
<td>16.4</td>
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Tristimulus colour measurement

A common set of scales developed by Hunter in 1942 are currently used on some instruments. The Hunter scales produce results in terms of L which is a lightness function and simulates Y: a predicts redness if positive and greenness if negative and b predicts yellowness if positive and blueness if negative. The L, a, and b colour scale is believed to approximate the way the human eye views colour; however, it does not take into account the eye’s ability to compensate for high or low levels of luminosity in judging colour differences. Hunter has taken this into account on some new scales which he has proposed (L, a’ and b’).

These scales are related to the present L, a, and b scales by the following relationships: L = L, a’ = 100 a/L, b’ = 100 b/L. These mathematical expressions are simply a scale expansion which take into account the low levels of luminosity and, therefore, expands a and b from the L, a, and b scales to a’ and b’ in the new scales.

SELECTED REFERENCES


V.K. Gupta


APPENDIX

NATIONAL & INTERNATIONAL STANDARDS FOR SENSORY EVALUATION OF DAIRY & FOOD PRODUCTS

A. BIS standards

4. Recommended methods for determination of aroma and taste threshold - IS : 10641- 1983
5. Sensory evaluation procedure to establish guidelines for open dating processed food products - IS : 10643 - 1983
10. Specification for testing glass for liquid sample - IS : 7999 - 1976
17. Methods for sensory evaluation of ghee (clarified butter fat) -
   IS: 7770-1975

18. Code for the evaluation of the effect of packaging and storage on the sensory qualities
   of food and beverages -
   IS: 8639-1977

B. IDF Standards

Recommended code of general practice for sensory grading of dairy products:

- Liquid milk
- Cream
- Butter
- Ice-cream
- Milk powder
- Cheese

IDF Standard 99A: 1987

Courtesy: Dr. S.K. Gupta, Principal Scientist, Division of Dairy Technology
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