EVALUATING THE SUITABILITY OF SAGO (TAPIOCA STARCH) IN DIETETIC LOW FAT ICE CREAM

A THESIS SUBMITTED TO THE ANAND AGRICULTURAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE (DAIRYING) IN DAIRY CHEMISTRY

BY

Ashishkumar Sureshchandra Patel B.Tech. (D.T.)

DAIRY CHEMISTRY DEPARTMENT SHETH M.C. COLLEGE OF DAIRY SCIENCE ANAND AGRICULTURAL UNIVERSITY ANAND 2008
ABSTRACT

EVALUATING THE SUITABILITY OF SAGO (TAPIOCA STARCH) IN DIETETIC LOW FAT ICE CREAM

Name of the Student                          Major Advisor
Ashishkumar S. Patel                                      Dr. K. D. Aparnathi

Dairy Chemistry Department
Sheth M. C. College of Dairy Science
Anand Agricultural University
Anand Campus, Anand

The present study was planned and conducted to evaluate the suitability of sago (tapioca starch) as fat replacer and bulking agent in dietetic low fat ice cream. Low fat and low calorie ice creams and frozen desserts are in high demand in market due to increased customer health awareness. In this study an attempt was made to prepare a low fat ice cream having 2.4 per cent fat using sago as a fat replacer and bulking agent, which was compared against a control ice cream having 10 per cent fat. Incorporation of sago resulted in nearly 30 per cent calorie reduction in low fat ice cream as compared to control.

For incorporation of sago in low fat ice cream a formulation was standardized i.e. form of sago, the level of sago, MSNF, sugar, stabilizer, emulsifier and flavourings. The selected tentative formulation was applied and three different categories of ice cream viz. plain, chocolate and fruit ice cream. The sago was gelatinized (85°C for 10 min) in skim milk medium (3.33 times by wt. of sago)
and then incorporated in ice cream mix. Such mixes were pasteurized (80°C for 5 min.), homogenized (2000 psi and 500 psi at 70°C), cooled (3-4°C), aged overnight at 3-4°C and then frozen in an ‘ice and salt’ type freezer. The ice creams were hardened in the same container at -18°C for 24 h. The samples of ice cream were also subjected to heat shock and storage study.

As per the variety of ice cream, minor changes were effected in the formulation as per need. Vanilla flavouring was used @ 0.8 ml/Kg mix for vanilla ice cream whereas in chocolate ice cream, it was used as an adjunct @ 0.4 ml/Kg of mix in addition to 2.0 per cent cocoa powder. Mango flavoured ice cream involved use of 20 per cent Alphonso mango pulp by wt. of ice cream mix. To impart rich pleasant taste to low fat ice cream, creamplus and butterbuds natural flavouring concentrates were used at 0.2 and 0.05 per cent respectively.

The ice cream mixes were analyzed for their proximate composition, viscosity and acidity. The fresh hardened ice creams were evaluated for chemical composition, physical properties and sensory characteristics. Heat shocked and stored samples were evaluated organoleptically.

The low fat vanilla ice cream had milk fat 2.38, protein 5.14, reducing sugars 7.95, Non-reducing sugars 12.87, and total solids 32.75 per cent. The low fat chocolate ice cream had milk fat 2.07, protein 5.57, reducing sugars 7.98, Non-reducing sugars 15.40, and total solids 36.70 per cent. The low fat mango ice cream had milk fat
2.38, protein 5.12, reducing sugars 8.00, Non-reducing sugars 12.86 and total solids 37.42 per cent. The control vanilla ice cream had milk fat 10.23, protein 4.61, reducing sugars 7.16, Non-reducing sugars 12.91, and total solids 36.19 per cent. The control chocolate ice cream had milk fat 10.18, protein 5.15, reducing sugars 7.21, Non-reducing sugars 15.44, and total solids 40.77 per cent. The control mango ice cream had milk fat 10.25, protein 4.74, reducing sugars 7.23, Non-reducing sugars 12.89 and total solids 41.13 per cent.

The resultant low fat ice cream had significantly lower fat and total solids compared to control ice cream, while it had significantly higher protein and lactose content. Sucrose content of all the ice creams was statistically similar. The acidity of low fat ice cream was statistically greater than control but within the normal range reported for ice creams. The overrun of low fat ice cream made using ‘salt and ice’ type freezer was 50-55 per cent which was at par with that of control statistically. Viscosity of sago containing low fat ice cream mix was significantly higher, which helped to produce desired body and texture, and impart nearly equivalent richness to those of control. The sago containing experimental ice creams had improved melting resistance.

The sensory score of low fat ice creams were enhanced by use of creamplus/butterbuds which made them sensorily at par with control. The CreamPlus was compatible with vanilla and mango flavourings, while butterbud was compatible with chocolate flavouring. The optimal rate of incorporation of creamplus and
butterbuds in low fat ice cream versions was arrived at 0.2 and 0.05 percent by wt. of ice cream mix respectively. In general for all the characteristics of experimental ice cream viz. flavour, body and texture, melting quality, colour and appearance; and overall acceptability were at par with control. The colour of low fat ice cream was improved i.e more prominent of darker shade for all the varieties of ice cream.

Use of sago along with marginal amount of sodium alginate could afford heat shock protection to low fat ice cream as does commercial stabilizers in control full fat ice cream. The suitability of the formulation containing sago was assessed for its commercial production through trial using direct expansion batch ice cream freezer. In commercial trial, the experimental product had 90-95 per cent overrun with dry appearance of scooped ice cream and having good organoleptic properties which compared well with control ice cream statistically.

The ingredient cost for one Kg ice cream mix for low fat ice cream and control arrived at Rs. 31.88 and Rs. 42.08 respectively. Sago can be successfully used in low fat ice cream without loss of sensory quality with attendant reduction of 30 per cent of calorie and cost reduction to the tune of 24 per cent.
Dr. K. D. Aparnathi  
Professor, 
Dairy Chemistry Department, 
Sheth M.C. College of Dairy Science, 
Anand Agricultural University, 
ANAND – 388 110 
Gujarat, India .

CERTIFICATE

This is to certify that the thesis entitled “Evaluating the Suitability of Sago (Tapioca Starch) in Dietetic Low Fat Ice cream” submitted by Mr. Ashishkumar Sureshchandra Patel in partial fulfillment of the requirements for a degree of Master of Science (Dairying) in Dairy Chemistry of Anand Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Anand
Date: / /2008

(K. D. Aparnathi) 
Major Advisor
ACKNOWLEDGEMENT

At this auspicious moment, I am at a loss of words to express my deep sense of gratitude and indebtedness to my Major Advisor Dr. K. D. Aparnathi, Professor, Dairy Chemistry Department, S. M. C. College of Dairy Science, Anand Agricultural University, Anand for his keen interest, most valuable and inspiring guidance and constant encouragement throughout the course of investigation. The years I have spent in his counsel and company will have an ever lasting positive impact on my professional career.

It gives great pleasure to express heartful thanks to my minor advisor Dr. A. H. Jana, Associate professor, Dairy Technology department for his keen interest, invaluable guidance and profound support at all time during my work tenure. I pay my due respect and thanks to Dr. B. P. Shah, Principal, SMC College of Dairy Science, Anand for the help and facilities provided.

I am very much thankful to the members of my advisory committee; Dr. S. Singh and Dr. H.G. Patel for their learned advice, helpful criticism and kind cooperation.

I am delighted to acknowledge my gratitude towards Dr. A. J. Pandya, Professor and head, Department of Dairy Processing and Plant Operations and Shri A. J. Gokhale for their ever-willing co-operation and fruitful suggestions.

I am highly thankful to Dr. S. K. Dixit, Dr. V. B. Darji and Mr. D. J. Parmar, Department of Agricultural Statistics, Anand Agricultural University for assisting in data analysis.

With great appreciation, I would like to thank Dr. M. J. Solanky, Dr. P. S. Prajapati, Dr. Suneeta Pinto, Dr. J. P. Prajapati, Dr. V. R. Boghra, Mr. Amit Patel, Hiral Modha, Mr. Bhavbhuti Mehta, Satish Parmar, Mr. Amit Jain, Ms Smitha and all the staff members of Dairy Technology and Dairy Chemistry department of SMC College of Dairy Science for their co-operation during the study and successful completion of this research work.
I must not fail to express my thanks to Mr. Sameer Saxena and Mr. Aditya Jain alumni of college, for their valuable guidance and others who have rendered direct or indirect help during the research work.


I wish to give special thanks to Duke Thompson India Ltd, Indore for providing the samples of “butter” and “cream” flavourings.

I would like to extend my deepest sense of appreciation and love to my parents and loving wife Chaitali. Without their love, moral support, sacrifice and blessings, my dream would not have been a reality.

Place: Anand
Date: -10-2008 (Ashish S. Patel)
## CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INTRODUCTION</td>
<td>01</td>
</tr>
<tr>
<td>2</td>
<td>REVIEW OF LITERATURE</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Genesis of ice cream manufacture</td>
<td>05</td>
</tr>
<tr>
<td>2.2</td>
<td>Definition</td>
<td>07</td>
</tr>
<tr>
<td>2.2.1</td>
<td>Frozen desserts</td>
<td>07</td>
</tr>
<tr>
<td>2.2.2</td>
<td>Ice cream</td>
<td>08</td>
</tr>
<tr>
<td>2.2.3</td>
<td>Low fat ice cream</td>
<td>08</td>
</tr>
<tr>
<td>2.3</td>
<td>Legal standards</td>
<td>09</td>
</tr>
<tr>
<td>2.3.1</td>
<td>PFA Standards of Ice cream</td>
<td>09</td>
</tr>
<tr>
<td>2.3.2</td>
<td>FDA standards of ice cream</td>
<td>09</td>
</tr>
<tr>
<td>2.4</td>
<td>Ice cream market in India and global trends</td>
<td>11</td>
</tr>
<tr>
<td>2.5</td>
<td>Technology of ice cream manufacture</td>
<td>12</td>
</tr>
<tr>
<td>2.6</td>
<td>Need for development of low calorie/dietetic ice cream</td>
<td>14</td>
</tr>
<tr>
<td>2.6.1</td>
<td>Obesity</td>
<td>15</td>
</tr>
<tr>
<td>2.6.2</td>
<td>Diabetes</td>
<td>15</td>
</tr>
<tr>
<td>2.6.3</td>
<td>Cardiovascular Disease (CVD)</td>
<td>15</td>
</tr>
<tr>
<td>2.7</td>
<td>Development of dietetic low fat ice cream</td>
<td>18</td>
</tr>
<tr>
<td>2.8</td>
<td>Effect of composition on the properties and quality of ice cream</td>
<td>20</td>
</tr>
<tr>
<td>2.8.1</td>
<td>Non-Dairy ingredients- their role in ice cream</td>
<td>20</td>
</tr>
<tr>
<td>2.8.1.1</td>
<td>Stabilizers</td>
<td>21</td>
</tr>
<tr>
<td>2.8.1.2</td>
<td>Emulsifiers</td>
<td>23</td>
</tr>
<tr>
<td>2.8.1.3</td>
<td>Sugar</td>
<td>24</td>
</tr>
<tr>
<td>2.8.1.4</td>
<td>Flavour</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>(A) Vanilla</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>(B) Chocolate</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>(C) Mango</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>(D) Cream and Butter flavours</td>
<td>27</td>
</tr>
<tr>
<td>2.8.1.5</td>
<td>Colour</td>
<td>28</td>
</tr>
<tr>
<td>2.8.1.6</td>
<td>Water and Air</td>
<td>28</td>
</tr>
<tr>
<td>2.8.1.7</td>
<td>Other additives</td>
<td>29</td>
</tr>
</tbody>
</table>
2.8.2 Dairy ingredients- their role in ice cream 30
  2.8.2.1 MSNF 30
  2.8.2.2 Milk fat 32
2.9 Fat replacers 34
  2.9.1 Definition 35
  2.9.2 Classification of fat replacers 35

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>TITLE</th>
<th>PAGE NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.9.3</td>
<td>Fat substitutes</td>
<td>36</td>
</tr>
<tr>
<td>2.9.4</td>
<td>Fat Mimetics</td>
<td>36</td>
</tr>
<tr>
<td>2.9.5</td>
<td>Rational in using fat replacers</td>
<td>37</td>
</tr>
<tr>
<td>2.10</td>
<td>Bulking agents</td>
<td>38</td>
</tr>
<tr>
<td>2.11</td>
<td>Carbohydrate based fat mimetics</td>
<td>39</td>
</tr>
<tr>
<td>2.11.1</td>
<td>Maltodextrin</td>
<td>39</td>
</tr>
<tr>
<td>2.11.2</td>
<td>Microcrystalline cellulose</td>
<td>40</td>
</tr>
<tr>
<td>2.11.3</td>
<td>Methylcellulose gums</td>
<td>41</td>
</tr>
<tr>
<td>2.11.4</td>
<td>Hydrocolloid Gums</td>
<td>41</td>
</tr>
<tr>
<td>2.11.5</td>
<td>Polydextrose</td>
<td>41</td>
</tr>
<tr>
<td>2.11.6</td>
<td>Pectin</td>
<td>42</td>
</tr>
<tr>
<td>2.11.7</td>
<td>Inulin (Rafﬁline) and Oligofructose (Rafﬁlose)</td>
<td>42</td>
</tr>
<tr>
<td>2.12</td>
<td>Starch</td>
<td>43</td>
</tr>
<tr>
<td>2.12.1</td>
<td>Chemistry of starches</td>
<td>43</td>
</tr>
<tr>
<td>2.12.2</td>
<td>Function and uses of starches in food products</td>
<td>44</td>
</tr>
<tr>
<td>2.12.3</td>
<td>Starch as stabilizer</td>
<td>45</td>
</tr>
<tr>
<td>2.12.4</td>
<td>Gelatinization of starch</td>
<td>46</td>
</tr>
<tr>
<td>2.12.5</td>
<td>Sago: A natural starch</td>
<td>51</td>
</tr>
<tr>
<td>2.12.5.1</td>
<td>Sago globules from tapioca</td>
<td>52</td>
</tr>
<tr>
<td>2.12.5.2</td>
<td>Production process</td>
<td>53</td>
</tr>
<tr>
<td>2.12.5.3</td>
<td>General composition</td>
<td>53</td>
</tr>
<tr>
<td>2.12.5.4</td>
<td>Grading of sago globules</td>
<td>54</td>
</tr>
<tr>
<td>2.12.5.5</td>
<td>Properties of sago</td>
<td>54</td>
</tr>
<tr>
<td>2.12.5.6</td>
<td>Virtues of sago</td>
<td>55</td>
</tr>
<tr>
<td>2.12.5.7</td>
<td>Production and Trade</td>
<td>56</td>
</tr>
<tr>
<td>2.12.5.8</td>
<td>Physical and chemical properties of sago</td>
<td>56</td>
</tr>
<tr>
<td>2.12.5.9</td>
<td>Gelatinization of sago starch</td>
<td>57</td>
</tr>
</tbody>
</table>
2.12.5.10 Digestibility of sago 57
2.12.5.11 Legal standards of sago 59
2.13 Ice cream mix properties 60
  2.13.1 Acidity 60
  2.13.2 Viscosity 60
  2.13.3 Whipping ability 61
  2.13.4 Colour of ice cream mix 62
2.14 Melting characteristics of ice cream 62
2.15 Cost and Calorie of ice cream 63

3 MATERIALS AND METHODS

3.1 Ingredients/Materials 65
  3.1.1 Dairy ingredients 65
    3.1.1.1 Milk 65
    3.1.1.2 Cream and skim milk 65
    3.1.1.3 Skim milk powder 66
  3.1.2 Non-Dairy ingredients 66
    3.1.2.1 Cane sugar 66
    3.1.2.2 Stabilizer 66
    3.1.2.3 Emulsifier 66
    3.1.2.4 Flavourings 66
      (A) Vanilla 67
      (B) Chocolate 67
      (C) Mango 67
      (D) Butter 67
      (E) Cream 67
    3.1.2.5 Sago 67
    3.1.2.6 Colour 67
  3.2 Preparation and processing of sago 68
    3.2.1 Gelatinization 68
  3.3 Preparation of ice cream mix 68
  3.4 Preparation of home made ice cream 69
  3.5 Freezing in direct expansion type batch freezer 71
  3.6 Analysis of the ice cream ingredients 72
    3.6.1 Milk 72
      3.6.1.1 Fat 72
      3.6.1.2 Total solids 72
### CHAPTER 3.6

#### 3.6.1

- **3.6.1.3** Titratable acidity 72

#### 3.6.2

- **3.6.2.1** Fat 72
- **3.6.2.2** Total solids 73
- **3.6.2.3** Titratable acidity 73

#### 3.6.3

- **3.6.3.1** Fat 73
- **3.6.3.2** Total solids 73
- **3.6.3.3** Titratable acidity 73
- **3.6.3.4** Solubility index 73

#### 3.6.4

- **3.6.4.1** Moisture content 74

#### 3.7

- **3.7.1** Fat 74
- **3.7.2** Total solids 74

### CHAPTER 3.7

#### 3.7.3

- **3.7.3.1** Titratable acidity 74

#### 3.7.4

- **3.7.4.1** Protein 75

#### 3.7.5

- **3.7.5.1** Reducing and Non-reducing sugars 75

#### 3.7.6

- **3.7.6.1** Ash 77

#### 3.7.7

- **3.7.7.1** Alkaline phosphatase test 77

#### 3.7.8

- **3.7.8.1** Viscosity 77

#### 3.7.9

- **3.7.9.1** Whipping ability 78

#### 3.7.10

- **3.7.10.1** Specific gravity 78

### CHAPTER 3.8

#### 3.8.1

- **3.8.1.1** Overrun 78

#### 3.8.2

- **3.8.2.1** Melting characteristics 79

### CHAPTER 3.9

#### 3.9.1

- **3.9.1.1** Heat shock treatment of ice cream 79

### CHAPTER 3.10

#### 3.10.1

- **3.10.1.1** Fresh ice cream 80

#### 3.10.2

- **3.10.2.1** Heat shocked ice cream 80

#### 3.10.3

- **3.10.3.1** Consumer preference test 80

### CHAPTER 3.11

- **3.11.1** Statistical analysis 80

#### 4

**RESULTS AND DISCUSSION**

#### 4.1

- **4.1.1** Formulation of sago based low fat ice 83
4.1.1 Milk fat and MSNF levels 84
4.1.2 Level of Sucrose 86
4.1.3 Type of gelatinization medium and its quantity 86
4.1.4 Level of Sago 87
4.1.5 Type and level of stabilizer 87
4.1.6 Type and level of emulsifier 89
4.1.7 Flavourings 90
4.2 Comparative appraisal of low fat with control ice cream 91
4.2.1 Low fat vanilla ice cream containing sago 91
  4.2.1.1 Chemical composition 92
  4.2.1.2 Physical properties 94
  4.2.1.3 Sensory quality 100
4.2.2 Low fat chocolate ice cream containing sago 105
  4.2.2.1 Chemical composition 106
  4.2.2.2 Physical properties 108
  4.2.2.3 Sensory quality 110
4.2.3 Low fat mango ice cream containing sago 112
  4.2.3.1 Chemical composition 113
  4.2.3.2 Physical properties 115
  4.2.3.3 Sensory quality 117
4.3 Heat shock resistance 119
4.4 Commercial ice cream freezing trial 123
4.5 Comparison of energy value of the dietetic low fat ice cream with an average ice cream 125
4.6 Comparison of cost of raw ingredients of the dietetic low fat ice cream with an average ice cream 126
5 SUMMARY AND CONCLUSIONS 129
REFERENCES i-xxviii
APPENDICES i-vii
<table>
<thead>
<tr>
<th>Table No.</th>
<th>Title of table</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>PFA (2006) standards for Ice cream as per ninth amendment</td>
<td>10</td>
</tr>
<tr>
<td>2.2</td>
<td>Microbiological parameters for ice cream (PFA, 2006)</td>
<td>10</td>
</tr>
<tr>
<td>2.3</td>
<td>Percentage market share of different Ice cream brands</td>
<td>11</td>
</tr>
<tr>
<td>2.4</td>
<td>Types of fat replacers</td>
<td>36</td>
</tr>
<tr>
<td>4.1</td>
<td>Tentative formulation of a low fat ice cream</td>
<td>90</td>
</tr>
<tr>
<td>4.2</td>
<td>formulation of a low and full fat vanilla ice cream</td>
<td>92</td>
</tr>
<tr>
<td>4.3</td>
<td>Chemical composition of vanilla ice cream</td>
<td>93</td>
</tr>
<tr>
<td>4.4</td>
<td>Physical properties of vanilla ice cream</td>
<td>95</td>
</tr>
<tr>
<td>4.5</td>
<td>Sensory quality of vanilla ice cream</td>
<td>101</td>
</tr>
<tr>
<td>4.6</td>
<td>Formulation of a low fat and full fat chocolate ice cream</td>
<td>106</td>
</tr>
<tr>
<td>4.7</td>
<td>Chemical composition of chocolate ice cream</td>
<td>107</td>
</tr>
<tr>
<td>4.8</td>
<td>Physical properties of chocolate ice cream</td>
<td>108</td>
</tr>
<tr>
<td>4.9</td>
<td>Sensory quality of chocolate ice cream</td>
<td>110</td>
</tr>
<tr>
<td>4.10</td>
<td>Formulation of a low fat mango ice cream</td>
<td>113</td>
</tr>
<tr>
<td>4.11</td>
<td>Chemical composition of mango ice cream</td>
<td>114</td>
</tr>
<tr>
<td>4.12</td>
<td>Physical properties of mango ice cream</td>
<td>115</td>
</tr>
<tr>
<td>4.13</td>
<td>Sensory quality of mango ice cream</td>
<td>118</td>
</tr>
<tr>
<td>4.14</td>
<td>Sensory characteristics of heat shocked vanilla ice cream</td>
<td>121</td>
</tr>
<tr>
<td>4.15</td>
<td>Calculated calorific value of the vanilla flavoured dietetic low fat vs. an average ice cream mix (per 100 g mix)</td>
<td>126</td>
</tr>
<tr>
<td>4.16</td>
<td>Estimated cost of raw materials required for 1.0 kg of low fat ice cream mix and an average ice cream mix</td>
<td>127</td>
</tr>
</tbody>
</table>
## LIST OF PLATES

<table>
<thead>
<tr>
<th>Plate No.</th>
<th>Title of Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sago used in the investigation</td>
</tr>
<tr>
<td>2</td>
<td>Flavouring materials i.e. cocoa powder, alphonso mango pulp and butterbuds</td>
</tr>
<tr>
<td>3</td>
<td>Ice &amp; Salt type freezer and direct expansion type batch freezer</td>
</tr>
<tr>
<td>4</td>
<td>Melting quality of vanilla ice creams</td>
</tr>
<tr>
<td>5</td>
<td>Vanilla flavoured control and sago containing low fat ice creams</td>
</tr>
<tr>
<td>6</td>
<td>Melting quality of chocolate ice creams</td>
</tr>
<tr>
<td>7</td>
<td>Chocolate flavoured control and sago containing low fat ice creams</td>
</tr>
<tr>
<td>8</td>
<td>Melting quality of mango ice creams</td>
</tr>
<tr>
<td>9</td>
<td>Mango flavoured control and sago containing low fat ice creams</td>
</tr>
<tr>
<td>10</td>
<td>Sago containing low fat and average fat control vanilla ice creams manufactured industrially</td>
</tr>
<tr>
<td>11</td>
<td>Sago containing low fat and regular fat control chocolate ice creams manufactured commercially</td>
</tr>
<tr>
<td>12</td>
<td>Sago containing low fat and average fat control mango ice creams manufactured industrially</td>
</tr>
</tbody>
</table>
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Title Appendices</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Average composition of dairy products employed in preparation of ice cream mixes</td>
<td>i</td>
</tr>
<tr>
<td>II</td>
<td>Ice cream score card</td>
<td>ii</td>
</tr>
<tr>
<td>III</td>
<td>Ice cream scoring guide</td>
<td>iii</td>
</tr>
<tr>
<td>IV</td>
<td>BIS specification of sago saboodana</td>
<td>iv</td>
</tr>
<tr>
<td>V</td>
<td>Food additives for use in ice cream/kulfi/dried ice cream mix/ frozen desserts/milk ices/milk lollies/ice candy</td>
<td>v</td>
</tr>
<tr>
<td>VI</td>
<td>Modified cassava starch and derivatives currently available in market</td>
<td>vii</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>--------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>°C</td>
<td>Degree Centigrade</td>
<td></td>
</tr>
<tr>
<td>CD (0.05)</td>
<td>Critical difference at 5 per cent level of significance</td>
<td></td>
</tr>
<tr>
<td>cm</td>
<td>Centi meter (s)</td>
<td></td>
</tr>
<tr>
<td>CV%</td>
<td>Coefficient of variation (per cent)</td>
<td></td>
</tr>
<tr>
<td>d</td>
<td>day (s)</td>
<td></td>
</tr>
<tr>
<td>°F</td>
<td>Degree Farenheit</td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>gram (s)</td>
<td></td>
</tr>
<tr>
<td>GMS</td>
<td>Glycerol Mono-Stearate</td>
<td></td>
</tr>
<tr>
<td>h</td>
<td>hour (s)</td>
<td></td>
</tr>
<tr>
<td>Kg</td>
<td>Kilo gram (s)</td>
<td></td>
</tr>
<tr>
<td>LA</td>
<td>Lactic acid</td>
<td></td>
</tr>
<tr>
<td>lb.</td>
<td>pound (s)</td>
<td></td>
</tr>
<tr>
<td>lit.</td>
<td>liter (s)</td>
<td></td>
</tr>
<tr>
<td>mg</td>
<td>milli gram (s)</td>
<td></td>
</tr>
<tr>
<td>min</td>
<td>minute (s)</td>
<td></td>
</tr>
<tr>
<td>ml</td>
<td>milli liter (s)</td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>milli meter (s)</td>
<td></td>
</tr>
<tr>
<td>MSNF</td>
<td>Milk Solids Not Fat</td>
<td></td>
</tr>
<tr>
<td>NS</td>
<td>Non significan</td>
<td></td>
</tr>
<tr>
<td>ppm</td>
<td>Parts per million</td>
<td></td>
</tr>
<tr>
<td>rpm</td>
<td>Revolutions per minute</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>Second (s)</td>
<td></td>
</tr>
<tr>
<td>SEm</td>
<td>Standard Error of Mean</td>
<td></td>
</tr>
<tr>
<td>TS</td>
<td>Total Solids</td>
<td></td>
</tr>
<tr>
<td>Wt.</td>
<td>Weight</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>WPC</td>
<td>Whey Protein Concentrate</td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER – 1

INTRODUCTION

Ice cream is a frozen mixture of a combination of milk solids, sweeteners, stabilizers, emulsifiers, colourings and flavouring. Other ingredients such as egg products and starch products may be used. India is a tropical country and hence the need of cold drinks and frozen milk foods has always been and would always be felt. Ice cream is a principal frozen milk food and its popularity is unmatched. It is generally considered a luxurious item. Any attempt to develop a highly nutritious frozen dessert, but at the same time reducing the cost, would go a long way in popularizing this nourishing as well as refreshing milk food.

Ice cream is a rich source of energy providing about 180 – 250 Kcal/ 100g. Further, milk fat is composed of higher concentrations of saturated fat and cholesterol to complicate the matters for conscious and people suffering from coronary heart problems and diabetes. It is reported that out of total 80 per cent of heart diseases, stroke and 40 per cent of cancers can be prevented through change in diet and lifestyle (Anon, 2008). Ice cream is a dairy product which is high in fat content (about 10-14 per cent) hence formulating low fat versions will help in greatly restricting the calorie intake. It is possible to reduce the calorie content of ice cream by using fat reduced or fat free recipes. Hence in the recent past there is a world wide growing interest of consumers towards low calorie foods including low calorie
ice cream varieties such as low fat, non fat, cholesterol free, and frozen desserts with low fat and sugar (Bray, 1991).

In recent years health conscious consumers are demanding for low sugar and low fat ice cream. For many producers, bridging this gap between health and luxury is the key to holding on to their share of the market. Thus a window of opportunity exists in the ice cream market for such products. However, formulating products, which will win consumer acceptance, is not that easy in practice. Indeed, market research conducted by Beneo-Orafti confirmed that consumer expectations are high when it comes to selecting a low fat alternative to traditional indulgence products (Wouters, 2008).

It is the high fat content of ice cream that gives consumers a feeling of satisfaction. The challenge for product developers therefore, is to reduce the fat content without discernable adverse influence on body, texture and flavour. In creating such low calorie products, manufacturers need ensure that in removing the guilt of consumption they should not diminish any of the enjoyment the consumers seek from such products.

The food industry has responded to changed dietary pattern by offering an ever increasing variety of new ingredients in the form of ‘fat replacers’ with improved food safety, stability and functionality. Such ingredients can be included in the formulation without significantly affecting the rheological and sensory characteristics of the resultant ice creams. It is claimed that fat replacers create a creamy sensation and improve meltdown properties to some extent. Fat replacer is a blanket term to describe any ingredient used to
replace fat (Jones, 1996). Some of the commercially available fat replacers are olestra, simplesse®, lycadex®, maltrin®, N-lite®, staslim™, N-Oil etc (Roller, 1996; Singer, 1996).

Apart from functioning as an energy source, fat also provide several functional and organoleptic properties in ice cream. Reduced calorie products usually have low total solids compared to standard products and consequently they make considerable demands on the functional ingredients such as emulsifiers, stabilizers, whey protein concentrates, fat replacers etc.

Since milk fat is the main contributor to the rich flavour and mouth feel associated with ice cream, its reduction brings about a host of body and textural problems such as coarseness/iciness, crumbly body, shrinkage and even flavour problems. Milk fat accounts nearly one third of the cost of ice cream and its substitution with cheaper fat replacers can help in substantially in reducing the cost of the final products and at the same time makes the products healthier (Sarkar, 2002).

Increasing preference of consumers towards natural ingredients has tempted ice cream manufacturers to search for new ingredients including the fat replacers. Starches open up new opportunities for manufacturers to create a wide variety of ice cream and frozen desserts with desirable melt in mouth textures and full, clean flavours even for low fat versions (Koxholt, 2000). In India, according to PFA rules (2006) as per ninth amendment, permits addition of modified starches singly or in combination at the rate of 30 g/kg (3%) maximum, subject to declaration on labels.

Introduction
Sago is well known as tapioca pearl or *saboodana* in Indian market. Process tolerant tapioca starches have a bland flavour profile and are ideal in delicately flavoured ice creams i.e. vanilla and strawberry. Koxholt (2000) reported that in addition to full flavour transparency tapioca starches are suitable for HTST and UHT systems. Sago doesn’t just exhibit exceptional technical attributes, it also delivers well documented health benefits such as nutritive and demulcent and destitute of irritating properties. Tapioca starch forms an excellent diet for the sick and convalescent. Hence in addition to marketing ice cream containing such ingredient on its fat reduced status, manufacturers can also focus on positive health attributes. Sago has a low caloric value (3.1 Kcal/g) compared to fat (9.0 Kcal/g).

Looking to the properties of sago, it can be used in the manufacture of low fat ice cream as fat replacer as well as bulking agent and stabilizer. The total solids level has to be adjusted to minimum 26 per cent so that the rheological and the sensory properties of such ice cream is not adversely affected. The gelatinized starch has thixotropic properties which imbibes greater amount of water in food system to give gelling like effect, affecting the mouth feel of product. However, no reports are available in the literature regarding use of sago in manufacture of low or full fat versions of ice cream. Therefore, present project has been contemplated with the following objectives.

(i) To study the gelatinization of sago starch
(ii) Incorporation of gelatinized sago in low fat ice cream
(iii) Evaluation of the low fat ice cream containing sago for its
physico-chemical, rheological and sensory characteristics

(iv) Evaluate use of creamplus and butterbud to improve the richness of low fat ice creams.

(v) Comparison of such dietetic ice cream with full fat ice cream even on commercial trial on batch freezers.

(vi) Cost effectiveness and calorie contributions of experimental ice cream as against full fat control ice cream.
CHAPTER – 2

REVIEW OF LITERATURE

Ice cream and frozen desserts, which include sherbets, ices, frozen yoghurts, dynamically and quiescently frozen novelties, and mellorine play a very important nutritional and social roles in our daily diet. The popularity of ice cream and frozen desserts is attributed to their refreshingly cool, delightfully sweet characteristics, besides the nutritive value (Marshall et al., 2003).

2.1 GENESIS OF ICE CREAM MANUFACTURE

The art of ice cream making was brought by Marco Polo from China to Italy in the 14th century and soon spread to France and rest of Europe. The first settlers took it across the Atlantic to North America, where its industrial manufacturing developed in the later half of nineteenth century (Blomdahl, 1982).

Many scientists and technologists have made their contribution to the development of ice cream as we know it today. Mention may be made of Jacob Fussel, who is considered as Father of wholesale ice cream industry, because in 1851, conceived the idea of utilizing surplus sweet cream in the manufacture of ice cream (Mortensen, 1923). In 1913 the direct expansion freezer was introduced and the continuous freezer was patented. In 1929 Cherry Burrell company produced continuous ice cream freezer commercially and the Creamery package continuous freezer was introduced in 1935 (Hyde and Rothwell, 1973). Works of Sommer (1951), Turnbow et al. (1947), Frandsen and Nelson (1950), Burke (1947), Frandsen and Arbuckle (1961),
Arbuckel (1972 and 1977), Hyde and Rothwell (1973) are well known in the development of ice cream. Early works of Mikhaylov et al. (1950) on flash pasteurization; Barber and Hodes (1951), Tracy et al. (1952), Theil and Burton (1952) and Patushov (1955) on HTST pasteurization of ice cream mix are also worth mentioning. Akhunov and Dzhabarov (1967) are known for their work on buffalo milk ice cream. Huse et al. (1984) for substitution of non-fat milk solids in ice cream with whey protein concentrate. Neshawy et al. (1988) made ice cream from hydrolysed lactose reconstituted milk. Abu-Lehia et al (1989) is known for ice cream manufactured from camel products. Ghosh and Coupland (2008) studied the Factors affecting the freeze–thaw stability of emulsions.


Muse and Hartel (2004) studied the structural elements of ice cream that affects melting rate and hardness. Guha and Yadav (2007) concluded that softy ice cream made with 75 per cent
fortification of buffalo milk with soymilk was acceptable using the probiotic strain of L. acidophilus at 10 per cent inoculum level.

India’s Ice cream market is valued at Rs. 2400 crores per annum (Bhushan, 2007). However, India’s per capita consumption of ice cream is just 500ml compared to an estimated 30 lit. in the USA and 1.2 lit. in China. So in India there is enough scope for more growth than the 8-10% observed over the past few years (Bhushan, 2007).

Ice cream is generally considered to be costly and luxurious item in India. Any attempt to develop a highly nutritious frozen dessert, at the same time economically in cost, would go a long way in popularizing this nourishing as well as refreshing milk food. Amul has recently launched low fat dietetic ice cream. Health conscious consumers are always on the lookout for ways to improve nutritional traits without sacrificing psychological satisfaction (Specter and Setser, 1994).

Now-a-days consumers seek health foods. Low calorie, reduced calorie and diabetic foods are becoming increasingly popular in all segments of the food industry. According to a recent market survey conducted in India, the consumers have cut back on the ice cream consumption because of fear of adverse impact on health (Ray, 2000). Therefore, it seems that healthier ice cream and frozen desserts for a specific group of people will be the focus point of prominence for the Indian ice cream manufacturer in the coming decade.
Though there is scanty information related to the present investigation, attempts have been made to cover the literature more relevant to the present work.

2.2 DEFINITION

Frozen dessert, Ice cream and low fat ice cream are defined by many scientists.

2.2.1 FROZEN DESSERTS

The broad term, frozen desserts, refers to ice cream and related products. Specific products include ice cream and its lower fat varieties, frozen custard, frozen yoghurt, mellorine, sherbet, water ice and frozen confections. Some of these desserts are served either soft frozen or hard frozen (Marshall et al., 2003).

2.2.2 ICE CREAM

Ice cream (glaces a la crème in French; Eiskrem in German; helado in Spanish; morozhenoe in Russian; Roomijs in Dutch; Fledies in Danish; gelato in Italian; sorvetes de crème in Portugese) is a frozen mixture of a combination of components of milk, sweeteners, stabilizers, emulsifiers and flavouring. Other ingredients such as egg products, colourings and starch hydrolysates may be present. This mixture, called a mix, is pasteurized and homogenized before freezing. Freezing involves rapid removal of heat while agitating vigorously to incorporate air, thus imparting desirable smoothness and softness to the frozen product (Marshall et al., 2003).

Webb et. al. (1974) defined ice cream mix as an oil-in-water emulsion in which the dispersed phase is the milk fat and the
continuous phase is an aqueous serum consisting of calcium caseinate - calcium phosphate micelles, serum proteins, carbohydrates and mineral salts. On the basis of particle size, the serum is a mixture of colloidal dispersion and true solution.

### 2.2.3 LOW FAT ICE CREAM

In USA “low fat Ice cream” means ice cream containing not more than 3 g of milk fat per serving of 4 fl oz, which can weigh as little as 60 g. Australia and New Zealand require not more than 3 g fat per 100 g of ice cream. In Canada this product with 3-5% fat is labeled as ice milk (Marshall et al, 2003).

### 2.3 LEGAL STANDARDS

Ice cream is a frozen dessert food, the formulation and manufacturing conditions under which it is made are controlled by legislation in most countries.

#### 2.3.1 PFA STANDARDS OF ICE CREAM

In India, according to PFA rules (2006) as per ninth amendment, Ice cream, Kulfi, chocolate ice cream or softy ice cream means the product obtained by freezing a pasteurized mix prepared from milk and/or other products derived from milk with the addition of nutritive sweetening agents (i.e. sugar, dextrose, fructose, liquid glucose, dried liquid glucose, maltodextrin, high maltose corn syrup, honey), fruit and fruit products, egg and egg
products, coffee, cocoa, ginger and nuts. It may also contain chocolate, and bakery products such as cake or cookies as a separate layer and/or coating. It may be frozen hard or frozen to a soft consistency. It shall be free from artificial sweetener. It shall have pleasant taste and flavour, free from off flavour and rancidity. It may contain permitted food additives given in the Appendix V. It shall conform to the compositional and microbiological requirements as given in the Table 2.1 and 2.2 respectively.

2.3.2 FDA STANDARDS OF ICE CREAM

According to FDA, ice cream is a food produced by freezing, while stirring a pasteurized mix (155°F/ 30 min or 175°F/ 25 s) consisting of one or more of the optional dairy ingredients such as caseinates, hydrolyzed milk proteins, non milk derived ingredients; excluding other food fats, except such natural compounds as flavouring ingredients which are added in incidental amounts to accomplish specific functions. Ice cream is sweetened with safe and suitable sweeteners and may be characterized by the addition of flavouring ingredients. Ice cream contains not less than 1.6 pounds of total solids to the gallon and weighs not less than 4.5 pounds to the gallon. Additionally for each 1 per cent increase in the milk fat content up to 14 per cent, the non fat milk solids (NFMS) content may be reduced by 1 per cent (FDA, 2002).

Table 2.1: PFA (2006) standards for Ice cream as per ninth amendment

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Requirements</th>
<th>Ice cream</th>
<th>Medium fat Ice cream</th>
<th>Low fat Ice cream</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Milk fat</td>
<td>Min. 10.0 per cent</td>
<td>Min. 5.0 per cent but Max.</td>
<td>Max. 2.5 per cent</td>
</tr>
</tbody>
</table>

Review of Literature Page 10
<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Microbiological parameter</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Total plate count</td>
<td>Max. 2,50,000/g</td>
</tr>
<tr>
<td>2.</td>
<td>Coliform count</td>
<td>Max. 10/g</td>
</tr>
<tr>
<td>3.</td>
<td>E.coli</td>
<td>Absent in 1 g</td>
</tr>
<tr>
<td>4.</td>
<td>Salmonella</td>
<td>Absent in 25 g</td>
</tr>
<tr>
<td>5.</td>
<td>Shigella</td>
<td>Absent in 25 g</td>
</tr>
<tr>
<td>6.</td>
<td>Staphylococcus aureus</td>
<td>Absent in 1 g</td>
</tr>
<tr>
<td>7.</td>
<td>Yeast and mould count</td>
<td>Absent in 1 g</td>
</tr>
<tr>
<td>8.</td>
<td>Anaerobic spore count</td>
<td>Absent in 1 g</td>
</tr>
<tr>
<td>9.</td>
<td>Listeria monocytogenes</td>
<td>Absent in 1 g</td>
</tr>
</tbody>
</table>

### 2.4 ICE CREAM MARKET IN INDIA AND GLOBAL TRENDS

The main global ice cream key players are Unilever, Nestle, McDonalds, Dreyers and Lotte Group. Ice cream industry in India has grown considerably. The liberalization process gave way to organized sector as it had been in the domain of small sector earlier. Total domestic market is estimated at Rs.1000 crore out of which organized sector accounts for about 65 per cent (Khanna, 2004). Major national brands are Amul, Quality Walls and Vadilal. Regional players are Mother Dairy, Arun, Joy, Nandini, Naturals, Dinshaw, etc. The per cent market share of different ice cream...
brands in India is given in Table 2.3. The branded market is worth 100 million lit. per annum valued at Rs. 600 crores (Sodhi, 2004).

**Table 2.3: Percentage market share of different Ice cream brands**

<table>
<thead>
<tr>
<th>Company/ Firm</th>
<th>Per cent market share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amul</td>
<td>32.0</td>
</tr>
<tr>
<td>Kwality Walls (HLL)</td>
<td>8.0</td>
</tr>
<tr>
<td>Vadilal</td>
<td>7.0</td>
</tr>
<tr>
<td>Mothe Dairy-Delhi</td>
<td>7.0</td>
</tr>
<tr>
<td>Dinshaw</td>
<td>4.0</td>
</tr>
<tr>
<td>Arun</td>
<td>4.0</td>
</tr>
<tr>
<td>Metro</td>
<td>3.0</td>
</tr>
<tr>
<td>Others</td>
<td>35.0</td>
</tr>
</tbody>
</table>

(HLL, 2004)

In recent years ice cream and frozen desserts market in India is witnessing a growth, which was never seen before. However, the consumption of ice cream in India is one of the lowest in the world, which is 0.1 lit. per person per annum compared to 22.0 lit. in US, 5.0 lit. in UK, 1.0 lit in Thailand, and even 0.41 lit. in Pakistan. The global average is 2 liter per annum. (Kumar, 2004).

Marshall et al (2003) reported that in the USA in year 2000 the consumption statistics for low fat and light ice creams were 24% and the nonfat ice cream was 2% of the total frozen desserts, which is increased in year 2008 to 28% in low-fat ice
creams and 2% is non-fat ice cream. However, in India figures for low fat ice cream are very low.

The branded market is expected to grow at the rate of 10 per cent annually. Even a 15-20 per cent growth rate has been reported (Anon, 2001). This clearly indicates that there is a scope in India for ice cream market to grow 10 times and match at least the global average (Sodhi, 2004).

It can be seen from the above data that in recent years ice cream and frozen desserts in India and world over is witnessing an explosive growth. However, since the consumers are becoming health conscious, the demand for dietetic/health foods is increasing.

2.5 TECHNOLOGY OF ICE CREAM MANUFACTURE

Detailed formulations and precise methods of manufacture differ amongst countries and also amongst manufacturers and the following process outline is open to considerable interpretation depending on the plant facilities available.

Home made ice cream freezer consists of a small metallic cylindrical vessel housed in a wooden bucket; the intervening space being filled with ice and salt (Salt being 20 to 30 per cent that of ice). The equipment is provided with a scraping-cum-beating device which is turned by a hand cranked gear wheel (Ohri, 1965; Hyde and Rothwell, 1973). Home made ice cream mix may or may not be homogenized. The approximate composition of home made ice cream being: milk fat, 10 to 14 per cent; MSNF, 6
to 6.5 per cent; sugar, 13 to 16 per cent; stabilizer and emulsifier, 0 to 0.5 per cent; total solids, 32 to 38 per cent (Arbuckle, 1977).

During ice cream manufacture, various dairy as well as non-dairy ingredients are chosen based on availability, cost or desired quality to supply the requisite amounts of milk fat, MSNF, sugar, stabilizer, emulsifier, flavourings, colourings with or without water. These ingredients are blended, pasteurized, cooled and aged to form ice cream mix (Arbuckle, 1986; Berger, 1990). After blending the ingredients, the mix is passed through a coarse screen into the homogenizer at a pressure of 136-170 Kg/sq. cm. with single stage, or at 170-204 Kg/sq. cm. with two stage homogenizer for an average mix at 69 to 71°C. This stabilizes the fat in water emulsion yielding fat globules of about 0.3 to 3.0 micro meter with an average of 0.45-1.0 micro meter (Berger and White, 1976). At the same time, homogenization also helps obtaining a smoother texture and aids in attaining better whipping characteristics. The homogenized bulk is maintained at this temperature for at least 30 min. in order to effect pasteurization by batch method. Other recommended pasteurization time-temperature combinations are 79.4°C for not less than 25 S by HTST method, 90°C for 1 to 3 S by vacuum and 100 to 130°C for an instant to 40 S by UHT method (Arbuckle, 1977). The mix is then cooled to around 5°C or lower and aged for 4 to 10 h. (Iversen and Pedersen, 1982). The aged mix is then pumped into a freezer, the freezing time and temperature being determined by the type of equipment used. Filtered air is incorporated under pressure towards the end of freezing and the whipping process takes place with scraped surface action on surfaces refrigerated at -20 to -33°C. In the continuous freezers,
the usual drawing temperature is 20 to 22°F (52 to 59 per cent water initially present in the mix is frozen), as compared with drawing temperature of 24 to 26 °C (30 to 41 per cent of water is frozen) in case of batch freezers. In advanced countries, the frozen ice cream is passed through a pressure relief valve and it is then either formed into blocks or filled into retail containers before passing it through an air blast tunnel for hardening which may take 40 to 80 min. at air temperatures as low as -46°C. Hardening rooms (forced air type) are commonly used for hardening of ice cream and are generally maintained at -20°C to -25°C. Plate or contact hardeners and nitrogen refrigerated hardened tunnels can also be employed for the purpose (Heath, 1978; Berger, 1990).

2.6 NEED FOR DEVELOPMENT OF LOW CALORIE/DIETETIC ICE CREAM

“Health is wealth” is a very well known proverb. In recent years affluence and globalization has made a different life style of Indians especially the middle class which constitute the major population of India. The Indian middle class has got the wealth but is fast losing its health. Paradoxically, a nation with 20 per cent poor of the world is facing an obesity crisis. We all know that fat is ugly, but many people are unaware that it is dangerous as well (Purie, 2006). So there is an urgent need to develop dietetic products. Further, the health and wellness concept has added a new dimension to this scenario. Consumption of diet high in animal fat is associated with incidence of obesity, coronary heart disease, hypertension, insulin resistance, cancer and gall bladder diseases (Swanson, 1998). This is mainly due to the following reasons:
2.6.1 OBESITY

According to FAO/ WHO release, 1.2 billion people are overweight and approximately 250 million people are obese. World over overweight is a bigger problem than undernourishment (Kumar, 2004). Obesity, till recently was seen as a disease of the developed countries. Yet 35 per cent of approximately 120 million Indians are seriously obese, as are one in ten urban Indian children (Purie, 2006). High fat intake is related to the development of nutrition related diseases, such as obesity, CVD and some forms of cancer. Therefore, nutritionists advise that dietary fat should contribute less than 30 per cent of total energy intake. However, representative diet studies show that daily fat intake in industrial countries is between 37 and 40 per cent of total energy intake (Menden, 1993; Singer and Moser, 1993).

2.6.2 DIABETES

Estimates of number of Indians harbouring diabetes vary, but even the more conservative figures suggest that at least 40 million. Indians are genetically predisposed to the disease. Some 1.6 million cases are diagnosed every year in India - one every 20 seconds. Experts say that tens of millions of Indians are walking around undiagnosed. That's an epidemic in which millions are at risk of irreversible damage to vital organs as blood sugar runs amok in their bodies (Pillai, 2006).

2.6.3 CARDIOVASCULAR DISEASE (CVD)

CVD is the leading cause of deaths in the most affluent societies all over the world. According to WHO estimates, 16.7
million people around the globe die of CVDs every year (WHO, 2003) and nearly 25 million deaths are estimate worldwide by the year 2020. CVD is now more prevalent in India and China than in other economically developed countries of the world added together. In India, specifically every ninth individual can be confidently suspected of having CVD (Krishnaswami, 2002). About 2.5 million Indians become victims of heart disease every year and Indian women are the fastest rising group of coronary patients in the world (Patel et al., 1998).

The alleged hypercholesterolemic effect of milk fat (Ney, 1991), and the desire to ensure overall good health (Sloan, 2000) have led consumers to demand reduced milk fat dairy products, including ice cream, in order to reduce the risk of coronary heart disease, the main cause of death in many western countries.

Conventional ice cream is a rich source of energy providing 180 to 250 cal/100g. Further, milk fat is composed of higher concentration of saturated fat and contains cholesterol to add which possess problems to calorie conscious people and people having coronary heart problems. Though people may be fond of ice cream, even as a precautionary measure they try to avoid consumption of ice cream on this ground. Bruhn et al (1992) reported that in USA 90% of women and 75% of men were concerned with what they eat and the way it affects their health. The most important factor in consumer decision to buy a product was taste, followed by cost and nutrition.

Since fat provides desirable texture, mouth-feel and flavour to many foods, many people are reluctant to switch to low-fat diet
(Drewnowski, 1992). Consumers would likely be satiated consuming a low-fat diet with the development of nonfat or low fat products with body and texture and mouth-feel at par with those of high fat products. On an average, more than 1000 new lower-fat and fat-free products have been introduced in the US annually since 1990. All of these products do not, however, succeed in the market place (Anon, 2000).

The low purchasing power of an average Indian makes ice cream unaffordable. Thus, efforts have been made by several investigators to develop cheaper ice cream by substituting the costlier milk based ingredients with cheaper alternatives (Lata, 1994). Fat is one of the costliest ingredients in ice cream, so reducing fat with some cheap ingredient with same organoleptic quality would be a win-win situation for the ice cream market.

Increasing preferences of consumers towards natural ingredients tempted manufacturers to search new natural ingredients of ice creams. There had been more than just subtle shifts in ice cream ingredients (Goff, 2004)

Ice cream business is to make available to consumers low caloric ice creams. One of the mean to reduce calorie is to reduce fat content of Ice cream (Schaafsma, 2004). Health and well being are linked inexorably to good food. Scientific research is now focused on the challenges of providing diets to individual that improve health beyond simply providing adequate nutrients. Few foods can be said to be as successful in providing the combination of delight and a sense of well being as ice cream (German, 2004). The natural organic dairy ice cream composition provides a frozen
product which possesses organoleptic characteristics of premium product, complies with organic labeling requirements and sports all natural ingredient composition free of added stabilizing gums and surfactants which are traditionally used in frozen desserts (Bray, 2004). Low calorie, reduced calorie foods are becoming increasingly popular in all segments of food industry (Larsen and Kumar, 2008).

Thus, the information above clearly indicates need for developing acceptable quality dietetic foods especially having reduced fat content. Formulating food product with reduced fat may provide health benefits to such people. Ice cream, being a rich source of fat contributes significantly towards its calorific value. Ice cream in particular has the potential for the development of dietetic lower-fat variants which may lead to increased sales (Olson et al., 2003).

2.7 DEVELOPMENT OF DIETETIC LOW FAT ICE CREAM

The calorie content of ice cream and frozen desserts is often declared in terms of cal/100g. The major contributors of calorie in these products are fat. To satisfy the consumer demands for new, nutritionally acceptable products, many types of new dietetic low fat ice cream have appeared in the market world over.

Reduction of fat content in ice creams has been of major interest to ice cream producers over the past decade. The trend to reduce fat to below 0.5 per cent in frozen desserts started in the US and has spread all over the Western world. Most ice cream companies have intensified research and development efforts to
develop low calorie frozen formulations which have body and texture characteristics of normal ice cream (Bhandari, 2001).

In literature a variety of dietetic/ low calorie ice cream and frozen desserts have been formulated using aspartame as a sweetener and a variety of bulking agents based on polydextrose, microcrystalline cellulose etc. (Wolkstein, 1986). Goff and Jordan in 1984 developed a calorie reduced frozen dessert having 30-40 per cent reduction in total energy compared to standard ice cream using aspartame and polydextrose. They reported that a usage level of aspartame between 0.05-1.0 percent and a maximum of 12 per cent polydextrose produced an acceptable product.

Rothwell (1985) developed formulation for diabetic and dietetic ice cream and comprising of 4 per cent milk fat, 15 per cent polydextrose, 0.5 per cent of microcrystalline cellulose, 0.2 per cent sodium citrate, 11.3 per cent MSNF, 0.75 per cent stabilizer emulsifier blend and 0.075 per cent aspartame.

Steinsholt and Longava (1985) suggested an acceptable low calorie ice cream product with 50 per cent less energy than standard ice cream. The manufactured ice cream contained 11 per cent MSNF, 4 per cent fat, 0.8 per cent stabilizer, 0.05 per cent aspartame and 12 per cent polydextrose and 1 per cent glycerol.

Verma (2002) formulated a dietetic frozen dessert with 5 per cent milk fat, 12.5 per cent MSNF, 9.9 per cent maltodextrin, 9.3 per cent sorbitol, 1.5 per cent WPC, 0.3 per cent stabilizer emulsifier blend and 400 ppm aspartame. Cody et al (2007) and Shaikh et al (2008) reported the use of rice flour in low fat vanilla ice cream.
Prindiville et al (2000) were made low fat and nonfat chocolate ice creams with 2.5% of milk fat, cocoa butter, or one of two whey protein-based fat replacers, Dairy Lo or Simplesse and reported Sensory Properties.

Thus, various workers have suggested different formulations of dietetic frozen desserts using high intensity sweeteners and bulk fillers such as polydextrose, maltodextrin, sorbitol, etc. Also to reduce the hardness of the product and get nearly the same freezing point depression as in standard ice cream various polyols such as sorbitol, lactitol, glycerol, etc. have been used.

2.8 EFFECT OF COMPOSITION ON THE PROPERTIES AND QUALITY OF ICE CREAM

The composition of ice cream varies in different localities and in different markets depending upon legal requirements, quality of product desired, raw materials available, plant procedures, trade demands, competition and cost (Arbuckle, 1977). Sommer (1951) recommended the composition of good average ice cream as fat, 12.5 per cent, MSNF 10 per cent, sugar 16 per cent, stabilizer 0.25 to 0.50 per cent, Egg yolk solids 0.5 per cent. Marshall et al (2003) reported the composition of low fat ice cream as fat, 2-4 per cent; MSNF, 12-14 per cent; sugar, 18-21 per cent (also includes low DE sugars); stabilizers and emulsifiers, 0.8 per cent; total solids 35-38 per cent.
An ice cream /ice cream mix is said to have satisfactory composition if it meets the requirements of cost, handling properties (including mix viscosity, freezing point and whipping rate of mix), flavour, body and texture, food value, colour and general palatability of the finished product (Arbuckle, 1977).

Turnbow et al. (1947) suggested that in discussing composition, the role of dairy ingredients (fat and MSNF) and Non dairy ingredients (sugar and stabilizer) needs to be critically evaluated.

2.8.1 NON DAIRY INGREDIENTS -THEIR ROLE IN ICE CREAM

A wide range of choice for non dairy ingredients for ice cream is available. The non-dairy ingredients include stabilizers, emulsifiers, flavours, colours, sweener solids, special products and water.

2.8.1.1 Stabilizers

Stabilizers are hydrocolloids which function through their ability to form gel-like structures in water by combining with water as “water of hydration”. Thus, they reduce the amount of free water in the mix and produce smoothness in body and texture, and retard or reduce the ice crystal growth during storage, provide uniformity of the product and resistance to melting (Bhandari, 2001). However, stabilizers did not directly affect initial ice crystal size distribution in ice cream structure (Flores and Goff, 1999).
Marshall et al (2003) reported the primary purposes for using stabilizers in ice cream are

a. To increase mix viscosity,

b. To stabilize the mix to prevent wheying off,

c. To aid in suspension of flavouring particles,

d. To reduce ice and lactose crystal growth due to heat shock

e. To prevent shrinkage of the product volume during storage

f. To provide resistance to melting

g. To produce smoothness in texture of ice cream

h. To produce a stable foam with easy cut-off and stiffness at the barrel freezer for packaging

I. To slow down moisture migration from the product to the package or the air,

The inhibitory effect on crystal growth is not due to modified thermodynamic or kinetic properties of water but to a mechanical hindrance exerted by the macromolecular system on the crystallization interface. (Muhr and Blanshard, 1986).

The hydrocolloid combinations used as stabilizers in non-fat and low-fat frozen dessert formulations differ from those in formulations containing fat because non-fat and low-fat formulations generally contain less solids, and thus require a higher degree of water binding. Furthermore, hydrocolloids
should contribute to creaminess and have fat sparing properties (Bhandari, 2001).

Potter and Williams (1950) listed the following factors as important in selecting a stabilizer; ease of incorporation in to the mix, effect on the viscosity and whipping properties of the mix, type of the body produced in the ice cream, effect on meltdown characteristics of the ice cream, ability of the stabilizer to retard ice crystal growth, quantity required to produce the desired stabilization and finally the cost.

Use of sodium alginate in ice cream has been studied extensively by Mack (1936), Anderson et al (1937), Stebnitz and Sommer (1938), Tracy and Tuckey (1939). The most practical method of adding sodium alginate is by mixing it with sugar or dispersing in water and adding it to the mix when the temperature of mix reaches to 160°F (Turnbow et al, 1947).

Hydroxypropyl methyl cellulose has been suggested for use in low fat frozen desserts. Colloidal Microcrystalline Cellulose can also be used advantageously in low fat mixes at a rate of 0.2-0.8 per cent (Marshall et al., 2003).

Pectin based fat replacers are also available. When processed under high shear, particles are formed that help to create fat mimetic properties. One commercial example is Slendid. Other gums and cellulosic substances can mimic some of the functions of fat. Some blends of gums interact synergistically to form microscopic spherical particles that mimic the rheology and mouthfeel characteristics of emulsified fat. These blends may contain guar, locust bean and xanthan gums, carrageenan,
sodium carboxymethyl cellulose and microcrystalline cellulose (Marshall et al., 2003).

2.8.1.2 Emulsifiers

Emulsifiers are surfactants which orient at the fat/water interface, with one portion of the molecule the fat loving or lipophilic portion attached to the fat, and another, the water loving or hydrophilic portion attached to the water. The primary effect of emulsifiers during freezing is related to their properties to partially demulsify the fat globules formed during homogenization. The partial de-emulsification is necessary in order that agglomeration and coalescence of the fat globules may take place during the freezing operation. Emulsifiers control fat agglomeration and coalescence, facilitate air incorporation, impart dryness at extrusion, impart smooth texture and consistency, improve resistance against shrinkage and improve melting properties (Bhandari, 2001; Marshall et al., 2003).

Mono- and di-glycerides are the most widely used emulsifiers in the production of low-calorie ice cream as they yield products having good structure, a creamy feeling in the mouth with slow and uniform meltdown. Generally, a formulation with a low fat content requires more emulsifier than a formulation with a relatively higher fat content. Recommended concentrations of mono- and di-glycerides with 60 per cent alpha mono content are 0.5 per cent in 3 per cent fat, low fat frozen dessert and 0.6 per cent in a 0 per cent fat mix (Bhandari, 2001; Marshall et al., 2003).
In a study conducted by Baer et al. (1997), four emulsifiers were evaluated in low fat ice creams (2% fat). Emulsifiers were polysorbate 80 blend with mono- and di-glycerides, 40 per cent alpha-monoglyceride, 70 per cent alpha-mono-glyceride and lecithin. The lowest flavour scores were obtained for sample containing lecithin. Emulsifiers increased the consistency or viscosity of low fat ice cream mix and reduced whipping times and ice crystal sizes. They also provided increased stability to heat shock. All the emulsifiers improved the body and texture of low fat ice cream. The emulsifiers also provided increased stability to heat shock.

The emulsifier added to the non-fat ice cream imparted a desirable resistance to heat shock; in addition to that emulsifier also resulted in smaller ice crystals, a major factor in improving the texture of nonfat ice cream (Baer et al, 1999). Baer et al (1997) studied the effect of emulsifiers on the body and texture of low fat ice cream and reported all emulsifiers improved the body and texture of low fat ice cream.

2.8.1.3 Sugar

It is an essential ingredient in ice cream to make a palatable product. It is also the cheapest source of solids in ice cream (Hyde and Rothwell, 1973). Sucrose, commonly known as granulated sugar, cane sugar and beet sugar, is the most widely accepted source of sugar.

Ice cream containing less than 12 per cent of sugar (sucrose) is likely to be criticized as lacking in sweetness. A sugar content of 17 per cent is very high in plain ice cream (Arbuckle, 1977). An
increase in sugar content of mix lowers the freezing point (Hyde and Rothwell, 1973; Arbuckle, 1977) leads to a marginal increase in viscosity (Nickerson and Pangborn, 1961) and reduces the whipping ability of mix (Arbuckle, 1977). It produces an ice cream which is soft and has a soggy rather sticky body (Turnbow et al., 1947; Sommer, 1951).

Reducing the sugar level in mix has no influence on the titratable acidity of mix, although it decreases specific gravity and viscosity of mix (Neshway et al., 1988). The resultant ice cream has increased resistance towards melting (Nickerson and Pangborn, 1961).

Various sweeteners used in ice cream include sucrose, invert sugar, dextrose, fructose, maltose, corn syrup, high fructose corn syrup, sorbitol, maltitol, xylitol, lactitol, glycerol, saccharin, sodium cyclamate, acesulfame-K, aspartame, etc. (Nicol, 1980).

2.8.1.4 Flavour

Flavour is generally considered the most important characteristic of ice cream. It need not be confused with word “flavour” in sensory evaluation, which includes the taste, the “feel sensation” of body and texture as well as the true flavour. The flavour of ice cream is the result of blending the flavours of all the ingredients, some of which may not be sufficiently pronounced to be recognizable, although each actually contributes to the final effect (Sommer, 1951; Arbuckle, 1977). There is an enormous range of flavouring available for ice cream that include natural products (i.e. cocoa powder, fruit pieces, citrus fruit pastes, nuts etc.), natural extracts and essence (i.e. vanilla extract, lemon
essence etc.), imitation flavourings (i.e. imitation strawberry, raspberry, banana flavours) and synthetic chemicals (i.e. vanillin, ethyl vanillin etc.) (Ohloff, 1972). The basic three varieties of ice cream are plain ice cream, chocolate ice cream and fruit & nut ice cream. In this study one flavour selected from each variety and that is Vanilla, Chocolate and Mango flavour.

Frost et al (2005) reported the sensory measurement of dynamic flavour intensity in ice cream with different fat levels (3%, 6% and 12%) and flavourings (berry, coconut, banana and vanilla). Although a wide variety of flavours are available the literature survey is limited only to “vanilla”, “chocolate” and “mango” flavour, used in this experiment.

Butter and cream flavours which are added to enhance the flavour of low fat products are also discussed here under.

(A) Vanilla

Vanilla is no doubt the most popular and widely used flavour in ice cream worldover (Jain and Verma, 1972; Arbuckle, 1977 and Steinitz, 1978). This delicate flavour makes up more than one fourth of the total volume of ice creams sold in the USA in year 2000 (Marshall et al, 2003).

(B) Chocolate

Chocolate is also one of the popular flavourings after vanilla for frozen desserts. Chocolate products used in flavouring ice cream are cocoa, chocolate liquor, blends of cocoa and chocolate liquor, chocolate syrups and extracts from cocoa nibs. Extra sweetener should be added to compensate for the bitter flavour of
cocoa, which is same weight of sucrose equivalent as of cocoa. Vanilla enhances chocolate flavour (Marshall et al, 2003).

Important flavour volatiles in cocoa include pyrazines, aldehydes, ketones, furans, other carbonyls, alcohols and esters. Cocoa powder also contains theobromine, caffeine, and other compounds that produce bitter and sour tastes; therefore, chocolate ice cream requires more sweeteners than do most other ice creams (Prindiville et al, 1999).

Cocoa powder used in the chocolate flavoured food products are good for us as they contain antioxidants and catechins which may prevent heart diseases, cancer and other degenerative illnesses (Anon, 2007a). Cocoa constituents exert beneficial effects on human health, and therefore cocoa may be considered functional foods (Borchers et al., 2000).

(C) Mango

The ice cream industry is a major market for fruits. There are many nutraceutical effects have been claimed for many fruits including mango. Fruit flavours are available as extracts from the prepared fruit, artificial compounds and true extracts fortified artificially. The amount of fruit required to impart the desired flavour depends upon the characteristic of the flavour and varies from 10 to 25 per cent of the weight of the finished product (Marshall et al., 2003). Mango is considering as a king of fruits and is like by all. So in this work mango flavour selected under the category of fruit flavoured ice cream. Geetha et al (2007) reported that mango contains high micronutrients and so frequently used
to get its health benefits, besides improvement in the taste of dairy products. Mango contains enzymes, which activate the metabolism and act to reduce inflammation (Anon, 2003). Mangoes are rich in anti-oxidants, (Vitamin A and C) which play an important role in the prevention of cancer and heart diseases (Deepmala et al, 2008).

(D) Cream and Butter Flavours

Enzyme modification technology is used to unlock the potent flavor elements in butter, cream, cheese and other flavorful fats, delivering highly concentrated natural flavours are now available in convenient powdered, paste and liquid form. These natural dairy concentrates are used at extremely low applications levels, and are kosher, halal, easy to use and stable in price. They allow the production of better tasting, more economical, healthier foods with very clean label statements (Grenus, 2004).

Dairy concentrates like butter bud, cream bud and cheese bud can be used to mask off flavors, round out flavor spikes, reduce fat, and heighten cheese, butter and cream flavors. Using these products allows the flavor to linger in mouth longer. A common mistake when using high-intensity flavors is using too much e.g. butter bud little as 0.1% can make a big difference in a product (Grenus, 2004).

2.8.1.5 Colour

Ice cream should have a delicate, attractive colour which is readily associated with the flavour. Only permitted colours should be used. Almost all flavours of ice cream should be adequately
coloured. Yellow colour is generally added to vanilla ice cream to give it the shade of natural ice cream produced in summer months. Fruit ice cream need to be coloured because the maximum commonly used fruit produces only a slight effect on colour. Chocolate ice cream is one of the exceptions. It is rarely coloured for the required amount of cocoa usually produces sufficient colour; if required caramel is added to give the required shade. Most colours are of chemical origin and are available either in liquid or paste form (Arbuckle, 1977).

2.8.1.6 Water and Air

Water and Air are important constituents of ice cream, but their effects are easily disregarded. Water is the solvent for the continuous phase. In frozen ice cream, it is present both as a liquid and a solid, as it will not completely freeze due to the effect of the added solutes on freezing point depression. The amount of air in ice cream influence both quality and profits and is involved in meeting legal standards (Marshall et al., 2003).

2.8.1.7 Other additives

Use of buffered salts improves the body and texture of ice cream. Sodium citrate and disodium phosphate are effective protein stabilizers particularly when protein instability is due to high acidity, high calcium and magnesium content or salt imbalance (Arbuckle, 1977 and Anon, 1991).

Use of sodium caseinate has been found to be advantages with regard to the whipping properties of the mix and the texture of final product (Bird et al, 1935). Nevertheless, it poses problems
such as imparting slight undesirable flavour, decreases the mix viscosity, increases the rate of melting and increases the mix acidity about 0.01 per cent for each per cent of sodium alginate used (Arbuckle, 1977).

Groundnut protein isolate can be utilized to replace about 40 per cent MSNF and 60 per cent MSNF in case of ice cream (Gabriel et al, 1986) and soft serve frozen dessert (Lawhon et al 1980) respectively. An ice cream formula comprising of 7.8 per cent groundnut protein isolate and 5 per cent coconut powder has been developed in Thailand (Beuchat et al, 1991).

Many of the proteins have the ability to depress the freezing point (anti-freezing proteins), promote ice nucleation, and/or reduce the rate of ice crystallization, thus blocking further growth of ice at that crystal surface in ice cream. These proteins have been reffered to as “Ice Struturing Proteins” (Marshall et al., 2003).

Das et al (1989) suggested the use of potato pulp to replace up to 25 per cent MSNF in ice cream, without impairing its organoleptic properties. Arrow root powder can also replace up to 40 per cent MSNF in ice cream, to give an acceptable product (Venkateshwarlu et al, 1990).

2.8.2 DAIRY INGREDIENTS- THEIR ROLE IN ICE CREAM

Dairy ingredients supply Milk fat and/or Milk solid-not-fat.

2.8.2.1 Milk SNF

MSNF content of mix is varied inversely with the fat percentage to insure proper body and texture (proteins); flavour
(lactose and minerals); and storage properties and are essential to the formation and maintenance of small air cells (Kilara, 1991a). MSNF is approximately 36.7 per cent protein, 55.5 per cent lactose and 7.8 per cent minerals (Arbuckle, 1977). The role of MSNF as a constituent of ice cream has been reviewed by many workers (Price and Whittier, 1931; Dahle, 1956; Hedrick et al, 1964; Braatz, 1969; Hall and Hedrick, 1971; Steinsholt, 1971; and Goff, 1992).

The proper amount of MSNF not only helps in producing a desirable body, but also prevents the ice cream from having a buttery taste. An excess of these solids should be avoided as they cause a salty flavour or sandy body and texture defect (Dahle, 1956).

The proteins in MSNF help to make the ice cream more smooth, compact and thus tend to prevent a weak body and coarse texture. Therefore, MSNF should be added as possible without getting into danger zone for sandiness. Too high concentrations, however, may impart an objectionable condensed milk flavour. Qualitative rather than quantitative variations of MSNF have an important influence on whipping ability. MSNF increases the viscosity and resistance to melting, but lowers the freezing point of ice cream (Doan, 1958; Doan and Keeney, 1965; and Arbuckle, 1977).

The high lactose concentration from high MSNF on crystallization causes a sandy defect (Dahle, 1956). It has been shown that low storage temperature, proper homogenization and stabilizers have retarding effect on lactose crystallization. A stabilizer containing marine and vegetable gums provided the
greatest protection, through actual physical interruption of the growth of crystal nuclei.

Prevention of lactose crystallization is of significant importance in preventing incidence of sandiness in ice cream (Nickerson, 1962). Numerous studies have been made on factors affecting lactose crystallization (Mojonnier and Tracy, 1922; Lucas and Spitzer, 1925; Leeder and Ostroff, 1966; Arbuckle, 1972; Guy, 1980, Hassan et al., 1984; Neshawy et al., 1988 and Lindamood et al., 1989).

Bothell (1920) advised limiting the lactose to 10 per cent of the combined weight of lactose and water in the mix. Dahle (1923) showed that setting an arbitrary figure for MSNF was impractical and if the percentage of MSNF was such that the concentration of lactose in water was not greater than 8.5 per cent, the ice cream did not become sandy under ordinary conditions.

Partial replacement (up to 25 per cent) of dried skim milk with whey powder in ice cream mix did not affect the mix properties significantly (Steinsholt, 1971). Various workers studied the use of whey solids in ice cream (Gopalanaidu et al., 1984; Naidu et al, 1986, Reddy et al., 1987, Khalafalla et al., 1975; Mathur and Shahani, 1979 ; Rothwell, 1984; Huse et al., 1984; Patel and Mathur, 1982; Thompson et al., 1983; Guy, 1980; Crowhurst, 1972; and Mathur and Srinivasan, 1979)

Many dairy ingredient such as liquid skim milk, concentrated whole or skim milk, sweetened condensed whole or skim milk, whole or skim milk powders, caseinates, whey protein

Review of Literature
concentrates, RO concentrates/UF retentates etc. are used alone or in combination, as the source of MSNF.

2.8.2.2 Milk Fat

By far the milk fat is the most important dairy ingredient going into the mix. It has a significant influence on composition, properties of the mixes and also on the final quality of ice cream obtained. Milk fat interacts with other ingredients to develop the texture, mouth feel, creaminess, and overall sensation of lubricity (Giese, 1996; Akoh, 1998).

Sommer (1951) found that ice cream with less than 10 per cent milk fat somewhat lacking in richness. Turnbow et al. (1947) found that ice cream with fat per cent of less than 8 would have more cooling effect. Fedeli (1976) owed the suitability of milk fat in ice cream to its smoothness. Milk fat contributes a characteristic richness and mellowness to the flavour of ice cream (Sommer, 1951; Kilara, 1991a). Arbuckle and Cremers (1954) concluded that milk fat give ice cream smoothness of texture that was difficult to obtain by any other means. Keeney (1962) stated that milk fat contributes to a subtle flavour quality, it is a good carrier and synergist for added flavour compounds and promotes desirable textural qualities.

Roland et al (1999a) studied the effect of fat content on the sensory properties, melting, colour and hardness of ice cream.

Ohmes et al. (1998) reported the sensory and physical properties of ice cream containing milk fat or fat replacers. They also reported that milk fat affects the flavour of ice cream in three
ways: by contributing its own natural richness and creaminess: by contributing flavours acquired through hydrolysis, oxidation, or processing; and by modifying the perception of flavourful substances in the product.

Prindiville et al (1999) studied the effect of milk fat on the sensory properties of chocolate ice cream. Cremers (1954) studied the distribution and arrangement of fat globules in the internal structure of ice cream and the effect of the fat air orientation upon the smoothness of ice cream and coagulated that fat particles concentrate towards the surface of the air cell during the freezing process in ice cream. Walker (1963) showed that milk fat along with protein, emulsifier and air contents affect the structure of ice cream.

Whitehead and Sherman (1967), while studying the influence of fat content and coagulated fat on the structure of melted ice cream concluded that by increasing fat from 0 to 10 per cent there was an increase in all the measured rheological parameters, between 6 and 8 per cent fat there was a significant change in structure. Keeney (1958) studied the fat stability problems in ice cream and found that milk fat tended to retard rate of whipping.

Considering recent demand of low fat and low calorie ice creams, various ingredients like hydrocolloids (Anon, 1989; Martin, 1987), dextran (Anon, 1979; 1990), oat bran (Inglett, 1990) and sucrose polyesters (Perotti, 1975; McCormick, 1988 and Anon, 1990) are being employed for filling up the void in solid owing to the missing contribution of fat and/or sugar to the total solids of
Typically, ice cream contains 10 to 16% fat. But in recent years, some ice cream manufacturers have reduced the amount of fat and replaced those fat solids with carbohydrates or proteins (LaBarge, 1988; Giese, 1996).

Milk fat contributes to a characteristic smooth texture to the ice cream and also helps to give body of ice cream (Moorthy and Balachandran, 1993). In addition to structure formation, it is difficult to reproduce the flavour of milk fat in low fat ice cream (Marshall et al, 2003).

Hyvonen et al (2003) reported only slight effect of fat on flavour release and flavour perception. But they reported that increasing fat content retard the melting of ice cream in the mouth. They also reported that intensity and sharpness of aroma and flavour were greater in fat free ice cream.

Kersiene et al (2008) investigate the impact of different concentration of milk fat and tapioca starch on the rheological properties of dairy custards and on the release of flavour compounds after different storage time. The presence of milk fat induced significant decrease of headspace concentration of flavour compounds.

Because of the crucial role played by fat in ice cream, it quickly became obvious that the development of low fat ice cream with matching quality of the full fat ice cream depended on replacing the fat with alternative ingredients which can impart physical and rheological properties as fat in low fat ice cream. These ingredients are known as fat replacers.

2.9 FAT REPLACERS
When fat is removed from foods many of the physico-chemical properties gets altered. This leads to a lower consumer response. To re-accomplish this loss, there is a need for suitable fat replacers, which are non toxic, cost effective and are able to mimic the fat without increasing the calorie intake. With growing health consciousness, consumers are demanding dairy foods with more nutrition without sacrificing taste and enjoyment (Mathur, 2008).

2.9.1 DEFINITION

The term fat replacer implies a substance that has certain desirable physical or organoleptic properties of the fat when it replaces fat without any of the undesirable properties of the fat. A fat replacer provide an opportunity for individuals to reduce intake of high fat foods and enjoy reduced fat formulations of familiar foods while preserving original sensory properties (Lucca and Tepper, 1994). Some of the commercially available fat replacers are olestra, simplesse®, lycadex®, maltrin®, N-lite®, stat-slim™, N-Oil etc (Roller, 1996; Singer, 1996).

2.9.2 CLASSIFICATION OF FAT REPLACERS

Fat replacers chemically resemble fats, proteins or carbohydrates and are generally categorized into two groups – fat substitutes and fat mimetics (Akoh, 1998).

On the basis of their origin and chemical nature, fat replacers broadly classified (Sroan and Kaur, 2003; Sachdeva, 2000) as follows:

1) Carbohydrate-based
2) Protein-based
3) Fat-based
4) Combination of fat the replacers

The different types of fat replacers available in the market are given in Table 2.4

**Table 2.4: Types of fat replacers**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type of fat replacer</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Carbohydrate based</td>
<td>Carrageenan, cellulose, gelatin, gellan gum, guar gum, xanthan gum, maltodextrins, polydextrose, starches, modified dietary fibers</td>
</tr>
<tr>
<td>2.</td>
<td>Protein based</td>
<td>Whey protein concentrate</td>
</tr>
<tr>
<td>3.</td>
<td>Fat based</td>
<td>Caprenin, Salatrim, mono- and di-glycerides, olestra</td>
</tr>
</tbody>
</table>

(Source: Anon, 2000)

**2.9.3 FAT SUBSTITUTES**

These are macromolecules that physically and chemically resemble triglycerides (conventional fats and oils) and which can theoretically replace the fat in foods on a one-to-one, gram-for-gram basis. Examples include sucrose fatty acid polyesters-Olestra/Olean, sucrose fatty acid esters, Trehalose, Raffinose, etc.

**2.9.4 FAT MIMETICS**

Fat mimetics are substances that imitate organoleptic or physical properties of triglyceride but which cannot replace fat on a one-to-one basis. Fat mimetics often called protein- or
carbohydrate-based fat replacers, are common food constituents e.g. starch and cellulose, but may be chemically or physically modified. The calorie values of fat mimetics ranges from 0-4 cal/g. Fat mimetics generally absorb a substantial amount of water (Akoh, 1998). Schmidt et al (1993) studied effects of carbohydrate or protein based fat mimicker on ice milk properties.

2.9.5 RATIONALE IN USING FAT REPLACERS

The Dietary Guidelines (USDA and USDHHS, 1995) recommend limiting total fat intake to not more than 30 per cent of daily energy intake, with saturated fats not exceeding 10 per cent and mono-unsaturated and poly-unsaturated fats accounting for at least two-thirds of daily energy intake (Bruhn et al., 1992).

As a food component, fat contributes key sensory and physiological properties. Fat contributes to flavour, or combined perception of mouth feel, taste and aroma/odour (Ney, 1988). Fat also contributes to creaminess, appearance, palatability, texture and lubricity of foods and increases the feeling of satiety during meals. Fat can also carry lipophilic flavour compounds, act as a precursor for flavour development and stabilize flavour (Leland, 1997).

In context with physiological standpoint, fat is a source of fat soluble vitamins, essential fatty acids and is a precursor for prostaglandins. Fat is the most concentrated source of energy in
the diet, providing 9 cal/g compared to 4 cal/g for both protein and carbohydrates.

Awareness of adverse effects of excessive dietary fat intake is virtually universal. Consequently, health conscious individuals are modifying their dietary habits and eating less fat (Miller and Grozaik, 1996). The consumer acceptance of any food product depends upon taste – the most important sensory attribute. Although consumers want foods with minimal to no fat or calories, they also want the foods to taste good. Food manufacturers continue to search for elusive “ideal fat replacer” that tastes and functions like conventional fat without the potential adverse health impact (Akoh, 1998).

Carbohydrate based bulking agents such as maltodextrin and polydextrose are currently used in low-calorie formulations because they produce minimal negative effects on ice cream production, shelf life and price (Roland et al., 1999b). Now it is possible for food manufacturers to replace fat with a fully digestible complex carbohydrate in a broad range of applications (Rai et al., 2000). Aime et al. (2001) demonstrated the use of modified pea starch as a partial fat replacer in vanilla ice cream.

At present there is no single ideal fat replacer that can mimic all the functional and sensory attributes of milk fat. As a result a systematic approach using several ingredients in combination is frequently desirable to achieve the characteristics of fat. Hence, there is a scope to utilize several ingredients, viz., polydextrose, maltodextrin, WPC, etc. singly or in combination to achieve the goal.
2.10 BULKING AGENTS

In order to produce ice cream which is sufficiently low in calories, it is necessary to reduce or remove sugar. Bulking agents are needed to replace loss of dry solids from the sugar and to retain an acceptable texture. A bulking agent can be defined as a low calorie food ingredient that can replace the bulk and functional properties of sugars. Generally carbohydrate or fiber based bulking agents bind water through molecular attraction, capillary action or by slowing the water molecule’s movement through a gel matrix. The ideal requirement for low calorie sugar replacers are as follows:

- they must be easy to handle
- they must have desired physical/chemical properties
- they must be cost efficient
- they must be legally permitted
- they should not have any adverse effect on shelf life and flavour

There are various bulking agents which have been tried out in ice cream. Brandt (2000) suggested polydextrose, maltodextrin and polyols as bulking agents suitable for ice cream. Some of these are discussed under. Patel et al (2007) reported the use of sago as a natural bulking agent in medium fat (6% fat) ice cream.

2.11 CARBOHYDRATE BASED FAT MIMETICS

The carbohydrate fat mimetics can be divided in maltodextrins, microcrystalline cellulose, methylcellulose gums,
hydrocolloid gums, polydextrose, pectin and inulin (Nayak et al., 2000; and Rai et al., 2000).

2.11.1 MALTODEXTRIN

Maltodextrins are GRAS, non sweet, nutritive (4 cal/g) mixtures of saccharide polymers of varying chain length. They are produced by partial hydrolysis of starch obtained from corn or potato starch. Maltodextrins obtained from oat, rice, wheat or tapioca starch are also available (Pal and Prabha, 2005). Size varies from 0.5 to 175 µ and shape ranges from spheres, ellipsoids, polygons, platelets and irregular tubules. The average molecular weight and degree of hydrolysis of maltodextrins varies up to dextrose equivalence (DE) of 20. Dextrose equivalence is the measure of the reducing sugar content, expressed as glucose. The molecular weight and DE determines the maltodextrin functional properties, such as viscosity/ bodying ability and browning ability. Maltodextrins are used to build solids and viscosity, bind/ control water, and contribute smooth mouth-feel in fat replacing systems for frozen desserts (Akoh, 1998).

Some of their important functional properties include bulking, gelling, crystallization, higher dispersibility, freezing point control and water binding. Maltodextrins are cheaper in comparison to other major edible hydrocolloids and their solution has a bland flavour and smooth mouth feel (Chronakis, 1998). Maltodextrin as bodying agents in fat-free ice cream significantly increased flavour release. Maltodextrin increased perceived fattiness and creaminess in fat-free ice cream (Hyvonen et al., 2003).
Tapioca based maltodextrins are produced by heating tapioca starch in the presence of hydrochloric acid. The gels are characterized by a bland flavour, smooth mouthfeel and a texture similar to that of hydrogenated fat (Sachdeva, 2000).


2.11.2 MICROCRYSTALLINE CELLULOSE

Microcrystalline cellulose (MCC) are non-fibrous forms of cellulose, ranging in size from less than 1 µ to 25µ, non-digestible, zero calorie food component and approved as GRAS by FDA. It is hydrophilic, water insoluble, linear, high molecular weight polymer consisting of ordered areas. Usage level varies from 0.1 to 10.0 per cent. MCC used in salad dressing, processed cheese, frozen dessert (Kanawjia and Khurana, 2006; Mather, 1998; Prindiville et al., 2000; and Welty, 2001).

2.11.3 METHYLCELLULOSE GUMS

They are water soluble polysaccharides which mainly include methylcellulose (MC, E-461) and Hydroxypropylmethyl cellulose (HMPC, E-464) in their group. The have stable in pH range of 3 to 11 and resistant to high temperature like 120° to
190°C. In liquid food they act as stabilizers. Successfully used in low calorie sources, dressings and frozen desserts (Mather, 1998; Sachdeva, 2000; Akoh, 1998; Kanawjia and Khurana, 2006).

2.11.4 HYDROCOLLOID GUMS

Gums are referred to as hydrophilic colloids or hydrocolloids which are long chain, high molecular weight polymers that dissolve or disperse in water. Viscosity and gelling properties affected by temperature, pH, solvent quality, ionic strength, presence of specific ions affects the ordered/disordered equilibrium in either one direction or the other. Galactomannans is a family which includes guar gum, locust bean gum and tera gum. The main functional properties of guar gum are thickening properties and water binding capacity (Kadian et al., 2000; Pederson, 1980).

2.11.5 POLYDEXTROSE

Polydextrose is a randomly bonded polymer of glucose, sorbitol and citric or phosphoric acid. Polydextrose is available in liquid or powdered and acidic or neutralized forms. Polydextrose is only partially metabolizable, providing 1 cal/g. Approved as a bulking agent, formulation aid, humectant and texturizer, polydextrose is used in several food categories including frozen dairy desserts and mixes, gelatins, puddings and fillings, hard and soft candy, jam, jellies, pastry, bakery fillings, cakes, biscuits, confections, toppings and frostings, instant drinks, cereal bars, extruded snacks, sauces, salad dressings and peanut spread.
Polydextrose can contribute slight smoothness in high moisture formulations and exerts fat-sparing effect. Polydextrose is recognized by FDA as a carbohydrate. Polydextrose is water soluble, low calorie (1 Kcal/g) and non-carcinogenic (Akoh, 1998; Jana et al., 1994; Kanawjia and Khurana, 2006). Goff and Jordan (1984), Abdou et al (1996), Akoh (1998) and Singh et al (2008) studied the use of polydextrose in low fat ice cream and frozen desserts.

2.11.6 PECTIN

Pectin is a purified carbohydrate collected from citrus fruits and apples. It is used as gelling agent for jams and jellies and in confectionary products, dairy products, fruit preparations, bakery filling for fat sparing. Usage level of pectin is 1.5 to 4.0 per cent is recommended (Pederson, 1980; Sachdeva, 2000; and Tiwary, 2005).

2.11.7 INULIN (RAFTILINE) AND OLIGOFRUCTOSE (RAFTILOSE)

Inulin and oligofructose classified as dietary fibers and probiotic substances contain only 1-1.5 kcal/g and are used as ingredients in low energy and diabetic ice creams. Inulin is an oligomer found in plants such as chicory and Jerusalem artichoke and has a high degree of polymerization of 2-60. Inulin can be used in products like table-spreads, frozen desserts, cheese products, meat products, fillings, sauces and meat replacers (Schaller-Povolny and Smith, 1999 and Tomomatsu, 1994). Wouters (1998) and Povolny and Smith (1999) reported the use of inulin and oligofructose in low fat ice cream.
In starch derived fat replacers, the parent starches are mainly from corn/maize (even waxy), potato and tapioca (Roller, 1996). Sago is also a source of plant starch. However use of sago as a replacer of fat in ice cream has not been studied so far. Therefore, the present project is contemplated in evaluating its effectiveness in low fat ice cream. Knowing the properties of sago, would help in understanding the way it would behave in a frozen food like ice cream.

2.12 STARCH

Starch is a major polysaccharide of higher plants where it occurs in organs such as seeds, tubers, or roots, and also in smaller quantities in stems and leaves. Starch is the reserve carbohydrate of plants and occurs as granules in the cell in plastids, separated from the cytoplasm. Most starch contains both amylose and amylopectin. Amylopectin is usually the more plentiful type of starch.

2.12.1 CHEMISTRY OF STARCH

Starch is a heterogeneous material consisting of varying proportions of amylose and amylopectin (Bule´on et al., 1998).

Amylose molecules are straight chain polysaccharides in which α-D-glucose units are joined 1-4. Chain length very from 250 to about 350 glucose unit, and the long molecules appear to be coiled in α-helix.

Amylopectin molecules are branched at carbon 6 on the glucose unit to form a 1-6 ether link. The length of the linear units
in amylopectin is only 25 to 30 units but molecular weights show that 1000 or more glucose units are combined in a molecule.

The ability of a natural starch to form pastes and gels differs considerably with the source of the starch. Amyloses are believed to form gels more readily because the linear shape allows the formation of a three dimensional network with ease (Meyer, 1960).

2.12.2 FUNCTION AND USES OF STARCHES IN FOOD PRODUCTS

Starch is added as a functional ingredient to many products such as sauces, puddings, confectionery, cornminuted meat and fish products and a variety of low-fat products. Starch is often added to fluid products to increase their viscosity and stability and also to semisolid products to contribute to their structure and thus improve their fat and water-holding properties (Hermansson and Svegmark, 1996).

The role of starch is progressing from that of being a cheap bulk ingredient to being a functional ingredient that is used because of its specific properties. This is especially evident in the recent development of a wide range of low-fat products (Hermansson and Svegmark, 1996). Starches are extensively used in a variety of food products such as ice cream, chocolate, milk-based sweets, jellies, sauces, custards and desserts (Abu-Jdayil, 2004).

Master and Steeneken (1997) described the influence of the components of skim milk (such as casein micelles, calcium phosphate, lactose and whey protein) on the rheological behaviour
of starch. Starch imparts body and mouthfeel to the dairy desserts (Imeson, 2000).

Verbeken et al (2004) reported that in dairy product containing starch and stabilizer, the requirement of stabilizer is less since the starch bound some of the free water and less free water available for the stabilizer to act.

Starches are used as a ingredient for thickening, binding agent, stabilizers, texturizers, fat replacers, gelling agents in various foods (Macrae et al., 1992a).

Starch can be used in the food industry for nutritional, technological, functional, sensorial and aesthetic purposes (Rai et al., 2000). Starches are led to provide desired properties such as viscosity, structure, mouth feel, stability and adequate water binding properties to minimize syneresis in dairy desserts (Rai et al., 2000). In addition of better rheological and organoleptic properties, modified starches also gave better over run (Rai et al., 2000).

The study was conducted by Surapat and Rugthavon (2003) to determine the effect of modified starch used as fat replacer on the sensory and physical properties of reduced fat coconut milk ice cream and improve the quality of reduced fat coconut milk ice cream by adding emulsifiers. Furesik (1992) reported that a high amylase maize starch has been used successfully in the manufacture of low energy ice cream from butter milk and skimmed milk, 50% fat being replaced by the starch base. Fat free yoghurt containing 0.5% modified tapioca starch showed similar quality with that of the control yoghurt having 3% fat either fresh or during cold storage (El-Aziz et al., 2004).
2.12.3 STARCH AS STABILIZERS

Plant derived polysaccharides are excellent stabilizing and thickening agents, and are used in many food systems (Hallagan et al., 1997). Hydrocolloids (stabilizers) are generally polysaccharides. Hydrocolloids are used to produce good body, smooth texture, slow melt-down and heat shock resistance in the ice cream and to retard and regulate the formation and growth of ice crystals (Gangopadhyay and Paul, 1990). Hydrocolloids prevent the formation of large lactose crystals and thus reduce the chances of sandiness in the ice cream (Wittenger and Smith, 1986). Tapioca starch is one of the natural hydrocolloids. Oleneve and Filchakova (1971) reported use of steam cooked potato starch as ice cream stabilizer. Koxholt et al (2005) reported that starch and starch derivatives in frozen desserts used to improve meltdown and shape retention. They reported that such additives inhibited ice crystal formation in frozen desserts after heat shock cycling.

Starch contributes greatly to the textural properties of many foods and has many industrial applications as a thickener, colloidal stabilizer, gelling agent, bulking agent, water retention agent and adhesive (Lii et al., 1996).

Martinez et al. (2005) patented use of starch and starch derivatives in frozen desserts for improved meltdown and shape retention. They reported the starch and starch derivatives can inhibit ice crystal formation in frozen desserts after heat shock cycling.

2.12.4 GELATINIZATION OF STARCH
A range of polysaccharides and polysaccharide mixtures are employed as gelling agents by the food industry. Morris (1998) classified the gelling polysaccharides as Algal polysaccharides (i.e. alginate, agar, carrageenans), Plant polysaccharides (i.e. pectins, starch, cellulose derivatives, galactomannans, glucomannans), Bacterial polysaccharides (Xanthan gum, gellan gum, curdlan, bacterial cellulose (cellulon™)) and polysaccharide mixtures (binary mixtures, phase separated gels, coupled gel networks, Ternary mixtures). Molecular basis of the transition from the ‘sol’ to ‘gel’ influence the gelation of polysaccharides.

During gelatinization, the granules swell and form gel particles. Gelatinization has been defined as phase transition of the starch granules from an ordered state to a disordered state, which takes place during heating in excess water. This transition always involves loss of crystallinity, loss of the anisotropic order (birefringence) and hydration of the starch. As long as water is abundant, gelatinization will occur at a fixed temperature range, normally 60-70°C. The swollen granules are enriched in amyllopectin. The linear amylose diffuses out of the swollen granule during and after gelatinization, and makes up the continuous gel phase outside the granule. This is the simple description of starch system after gelatinization (Hermansson and Svegmark, 1996). Starch granules when exposed to water, undergo swelling and upon heating undergo a process of irreversible swelling and crystalline melting called gelatinization (Macrae et al., 1992b).

Gelatinization depends on number of factors viz starch variety, pH of the gelatinization medium, time-temperature
gelatinization, size of granules (Meyer, 1960). Sugars were found to increase the gelatinization temperature in the following order: (water alone) < ribose < fructose < glucose < maltose < sucrose (max. temp.).

The microscopic appearance of the starch granules changes markedly on heating, in three stages. The first stage (reversible), in cold water, is marked by the imbibitions of approximately 25 to 30 per cent of water. The viscosity of starch-water system does not change in this first stage. The second stage (not reversible) occurs at gelatinization at 65°C for the most starches, when the granules begin to swell rapidly and take up a large amount of water. The granules change in appearance during this second phase, and some of the more soluble starch molecules are leached out of the granule. The third stage is marked by more swelling. The granules become enormous, often a void is formed, much more starch is leached out, and finally the granule ruptures, spilling more starch out into the surrounding fluid. The viscosity of the fluid increases markedly during third stage and the starch granules stick together so that they can no longer be picked apart (Meyer, 1960).

The swelling of starch, particularly amylose, which results in an increase in viscosity of a starch-water mixture and the formation, under proper condition, of gel is now believed to occur through the binding of water. Amylose and amylopectin in starch molecule are loosely bound together by hydrogen bonds of the hydroxyls. As the temperature of starch-water mixture rises, hydrogen bonding decreases. The tiny water molecules begin to freely penetrate between starch molecules. Conversely, as the temperature decreases, water molecules are bound between the
starch molecules and there is an increase in size or swelling. Two starch molecules were originally bound together, there are now the two starch molecules with water molecule is between. Gel formation occurs through the formation of a three-dimensional network of starch molecules, particularly the long straight chain amylose molecules (Meyer, 1960). Gel formation of starch is believed to be primarily the function of amylose rather than amyllopectin.

Starch granules dispersed in water exhibit a limited degree of swelling and the process is exothermic (Sair and Fetzer, 1944). Irreversible swelling of granules occurs when the dispersion is heated above the gelatinization temperature (Leach, 1965; Collison, 1968). The transition is endothermic (Donovan, 1979). Gelatinization results in a loss of molecular orientation and a breakdown of the crystalline structure. Swelling of the granules leads to solublization of the amylose. Under shear the granule structure may break down in to fragments freeing amyllopectin. Under non- shearing conditions there is little evidence for the release of substantial quantities of amyllopectin, even on heating to 100°C. Thus heating results in porous amyllopectin based granules suspended in a hot amylose solution. On cooling the samples form turbid viscoelastic pastes or, at sufficiently high polysaccharide concentrations (>6% w/w), they form opaque thermoirreversible elastic gels. Several authors have recognized the composite nature of starch gels (Eliasson and Bohlin, 1982; Ring and Stainsby, 1982).

The characteristics of starches, such as viscosity, shear resistance, gelatinization temperature, solubility, gel stability and
texture, are all functions of the amylose to amylopectin ratios (Yong et al., 1998).

The role of amylose in starch gelation has also been recognized by many authors. Gelation properties improved roughly with increase in amylose content (Steeneken and Woortman, 2008). Hermans (1949) envisaged an amylose-amylopectin network akin to the classical fringed miceller gel structure. Ott and Hester (1965) demonstrated that amylose forms opaque elastic, thermoirreversible gels at concentrations > 1.5 % w/w. Studied by Ott and Hester (1965) on cross-linked granules showed that solubilisation of a sufficient quantity of amylose was an essential requirement for the gelation of starch. These workers also demonstrated that swollen granules reinforce amylose gels and postulated amylose-amylopectin binding of granules in to a network.

In most practical applications, the gelation process will involve conversion of the weak, temporary network into a strong permanent network. The branched polysaccharide amylopectin will also gel (Ring et al., 1987). Gelatinization of starch in the presence of shear results in a mixture of amylose and amylopectin. Starch gels are composites consisting of swollen granules embedded within an interpenetrating amylose gel (Morris, 1998). Studies on starches from different botanical sources (Orford et al., 1987) showed similar roles for amylose and amylopectin during gelation.

Gelatinization describes several changes in the starch granules, which include loosing crystallinity, absorbing water, swelling, and leaching of some components (Tsai et al, 1997).
Yue Li et al. (2008) studied the structure-viscosity relationship for starches from different rice varieties during heating.

Noda et al. (2008) studied the factors affecting the digestibility of raw and gelatinized potato starches. Garcia-Alonso et al. (1999) studied parameters involved in the gelatinization of starch.

Ratnayake and Jackson (2007) studied gelatinization process of native starches including tapioca and concluded that starch gelatinization process is more complex.

Sakonidou et al. (2003) discussed the role of agitation in gelatinization under conventional heating. They reported that both mixing and heat transfer are promoted by the agitation.

Abu-Jdayil et al. (2004a) reported that the degree of gelatinization of starch heated at 60 to 75°C is insufficient for the starch-milk-sugar system. They concluded that the temperature range 75-85°C is give sufficient degree of gelatinization. Abu-Jdayil et al. (2004b) reported the effect of type and concentration of starch, sugar and milk on the gelatinization behavior.

Starch suspensions were heated into the solution state and cooled, spreadable particle gels were obtained with a spherulite morphology and a cream-like texture. This so-called superheated starch (SHS) exhibits more effective gelling properties than maltodextrin, which is currently applied as a fat mimetic (Steeneken and Woortman, 2008).
Suspensions of gelatinized starch granules in water behave as assemblies of solvent-swollen gel particles (Evans & Lips, 1992; Steeneken, 1989). 

Due to gelatinization of starch the water holding capacity and viscosity of dispersion is increased (Tyagi and Tyagi 2005). Freeze-thaw stability are also a characteristics of pregelatinized starches (Macrae et al., 1992a).

A large number of techniques, such as differential scanning calorimeter (DSC) (Donovan, 1979), X-ray diffraction (Zobel et al., 1988), small angle neutron scattering (Jenkins, 1994), Kofler hot stage microscope (Watson, 1964), Electrical conductivity (Bauer and Knorr, 2004) have been used to study gelatinization behavior of starches.

2.12.5 SAGO: A NATURAL STARCH

Sago is a processed edible natural starch marketed in the form of small globules or pearls. The name sago originated from Malaya and East Indie. There are several sources of sago especially the sago palm (*Metroxylon Sagus* or *Metroxylon rumphii*) and palm fern (*Cycas circinalis*). Other sources of sago include *Cycas rovoluta, Sagus farinifera, Sagus rumphii*, *Convovolus batalas*, and *Areca oleracea*. Sago is also manufactured in various countries from starches of tapioca, potato, sweet potato and maize. In India, the sago of commerce is manufactured mainly from tapioca starch (Johnsons and Peterson, 1974). It is known as tapioca pearl or *sabudana* in Indian market.
Rasmussen (1988) reported that foods of the future will contain more of natural substances. Hippocrates said “Let food be your medicine and medicine be your food”. These words of Hippocrates and Arnot hold true for the dairy and food industry as well (Gherty, 1994).

2.12.5.1 Sago globules from Tapioca

Tapioca starch is obtained from the large tuberous roots of the cassava plant (*Manihot utilissima* Pohl, *Manihot esculanta*) which grows in many equatorial regions (Macrae *et al.*, 1992a). There are over 2000 varieties of the plant (*Manihot utilissima*, the bitter type, and *Manihot palmate*, the sweet) which is a member of family of Euphorbiaceae. These bitter and sweet varieties contain relatively greater or lesser amounts of prussic acid throughout the plant. The bitter component comes out about through the action of glucoside contained in the plant juices. The so called bitter varieties are cultivated for commercial tapioca starch manufactured because of the higher yield. All the prussic acid disappears in the starch extraction process. The names “tapioca”, “manioc” and “cassava” all refer to the same thing.

Tapioca (*Manihot utilissima*) a low shrubby plant 2-5 m high with a cluster of tuberous roots, is a native of South America, India and other far Eastern countries. It is usually propagated by cutting of the stem. Planting at the beginning of the monsoon is preferred if the tubers are required for the sago manufacture. The crop is ready for harvesting from the eighth month onwards. For harvesting, the plants are pulled out and tubers separated. Each plant yields 5-10 tubers, usually 10-20 in. long, sometimes even
as long as 2-3 ft. Each tuber weighs about 2-5 lb. and roots weighing as much as 25-30 lb. have been reported (Johnsons and Peterson, 1974).

2.12.5.2 Production process

Sago pearl or tapioca pearl is obtained from cassava root only by physical modification as given in appendix V (Klanarong et al, 2002). The outer skin of tapioca tuber is removed by scraping with small knives leaving a white tuber containing starch. The tubers are crushed finely in mechanically operated grinders in which water is allowed to trickle down through a perforated pipe. The starch slurry is passed through a cloth screen whereby the starch milk is separated from the fibrous material. The fibrous waste so obtained is taken out, dried, and powdered for use in the match and textile industries. The pure starch slurry is conveyed to settling tanks and the starch scrapped out after draining the water (Johnsons and Peterson, 1974).

To prepare pearl sago, the moist starch is pressed through a perforated sheet of iron or coarse screen. The pellets of starch are put into a shallow hammock-shaped cloth to which a circular swinging motion can be imparted. Swinging this contraption in the correct posture imparts a rotary motion to the pellets which, provided the moisture content is correct, become roughly spherical in shape. The pellets are compact enough for screening to remove fine particles and large aggregates. The sieved pearls are then roasted in the shallow metal pans for partial gelatinization and drying as sago pearls (Johnsons and Peterson, 1974).

2.12.5.3 General composition
The quality of tapioca sago depends largely on the quality of starch from which it is derived. Sago has reported to have: 12.2% moisture, 0.02% nitrogen, 0.25% total ash, 0.06% acid insoluble ash and 5.6% fiber (Johnsons and Peterson, 1974). The pH of aqueous extract is reported in between 4.2 to 5.2.

2.12.5.4 Grading of Sago globules

Sago globules are classified according to size, colour and degree of roasting: Grade I, milky white globules, well roasted; Grade II, colour slightly dull, but well roasted; Grade III, colour dull but containing a small percentage of half-roasted globules; and Grade IV, other than those specified above. Sago is packed in gunny bags (202 lb per bag) for the market (Johnsons and Peterson, 1974).

2.12.5.5 Properties of sago

The properties of sago are,

- Granular size: Variable 20-60µ
- Granular shape: Egg shape with truncated forms
- Approximate amylose/amylopectin: 27/73%
- Gelatinization temperature range: 60-72°C
- Total lipid content: Very low
- Paste clarity: Translucent
- Paste structure: Long, stingy fluid body
- Paste strength under mechanical shear and prolonged heat: Medium/low
- Paste viscosity: Medium/high, moderate
Kuntz (2006) reported Tapioca’s round granules ranges from 5 to 25 microns and the granules consist of approximately 17 per cent amylose of high molecular weight. Meyer (1960) reported the 18 per cent amylose in tapioca starch. Macrae et al. (1992a) reported for tapioca starch, water: 12 per cent, pH: 6.3-6.5, amylose: 16 per cent, amylopectin: 84 per cent and granule size: 5 to 15 microns. They also reported the tapioca starch properties during cooking in water; fast rate of granule swelling, moderate viscosity during cooking, moderate swollen granule fragility, low retrogradation of linear polymers.

Cassava starch has many remarkable characteristics including high viscosity and high freeze-thaw stability which is advantageous in food products like Ice cream (Klanarong et al, 2002). Food scientists recognized tapioca as a unique valuable stabilizer (Kuntz, 2006). Tapioca produces glossy appearances and has a bland flavour. Tapioca is very bland in taste and is well suited for mildly flavoured applications (Kuntz, 2006). Native tapioca is a popular choice for natural and organic foods. Tapioca is reported as non-GMO and non-allergic (Kuntz, 2006). Pearl tapioca, the form used in food preparation requires soaking in water before cooking.

2.12.5.6 Virtues of sago
Sago is used as an infant and invalid food and in the preparation of puddings. Sago is nutritive and demulcent, and is a convenient and agreeable ingredient for making puddings, gruel, and diet for the sick room (Felter and John, 1898). Being destitute of irritating properties, tapioca starch forms an excellent diet for the sick and convalescent (Remington et al., 1918). In vitro digestibility studies have shown that the digestibility of cooked sago is greater and faster than raw starch (Johnsons and Peterson, 1974).

Starch that avoids hydrolysis by amylolytic enzymes in the small intestine and passes to the large bowel for fermentation is defined as resistance starch (Thompson, 2000).

Kuntz (2006) reported that tapioca is a valuable stabilizer in food applications. Tapioca is very bland in taste and is well suited for mildly flavoured applications. From processing standpoint it gives a more-stable end product with a uniform consistency and a better flavour profile. In dairy applications, it improves overall taste through influence on mouth-feel.

Tapioca and Waxy maize starches are mostly used as bases for commercial modification since most desirable properties are obtained from their derivatives but not those from rice, wheat or high amylose corn starches (Wattanachant et al., 2002).

2.12.5.7 Production and Trade

India is not importing sago and only small quantities of tapioca and sago products are exported according to data (Johnsons and Peterson, 1974). India produced 58,00,000 million
tones cassava roots which is 3.3 per cent of world production in year 2001 (Sriroth et al., 2002).

### 2.12.5.8 Physical and chemical properties of sago


Tietz et al. (2008) studied the interaction between tapioca starch and aroma compounds as measured by proton transfer reaction mass spectrometry (PTR-MS).

Kolhe et al. (2007) prepared paneer from buffalo milk blended with sago powder and concluded that use of 0.5 % sago powder increases the yield of paneer from 20.43 per cent to 22.13 per cent. Sandoval-Castilla et al. (2004) reported the use of modified tapioca starch as fat replacer in preparation of yogurt.

Muadklay and Charoenrein (2007) studied the effect of hydrocolloids and freezing rates on freeze-thaw stability of tapioca starch gels. Itthisoponkul et al. (2007) studied the inclusion complexes of tapioca starch with flavour compounds.

### 2.12.5.9 Gelatinization of sago starch

The tapioca starch is observed to be almost insoluble in water at 20°C, but upon heating to 70°C it solublizes in water up to 14.36% (Mishra and Rai, 2006). Tapioca starch yields high swelling power and exhibits a maximum value near 80°C (Jeng-Yune and Yeh, 2001). Irreversible tapioca starch granular swelling
occurred at 70°C (Ratnayake and Jackson, 2007). Tarrega et al. (2005) studied the heating of tapioca starch in milk and they reported that samples showed a clear gel like behavior.

2.12.5.10 Digestibility of sago

Han and Bemiller (2007) studied the physical characteristics of slowly digesting modified food starches. Starch products vary in digestibility. The rate and extent of digestion is reflected in the magnitude and duration of the glycemic response. The Most starch products contain a portion that digests rapidly (rapidly digesting starch, RDS), a portion that digest slowly (slowly digesting starch, SDS), and a portion that is resistant to digestion in the time frame of the test (resistant starch, RS) (Englyst and Hudson, 1996).

Gelatinization enhances the ability of starches to absorb large quantities of water, and this lead to improve digestibility also it increases speed at which enzymes can break down the linkages of starch, thus converting starch into simpler and more soluble carbohydrates (Tyagi and Tyagi, 2005). Sago is used as an infant and invalid food (Johnsons and Peterson, 1974). In vitro digestibility studies have shown that the digestibility of cooked sago is greater and faster than raw starch (Johnsons and Peterson, 1974). Being nutritious and the same time easy of digestion and destitute of irritating properties, tapioca forms an excellent diet for the sick and convalescent (Remington et al 1918a). Sago is nutritive and demulcent. As per a report, diet prepared for invalids; in cases of indigestion, chronic dysentery, etc is composed of sago (Felter et al., 1898a). Pearl sago chemically considered a very pure natural starch which is used exclusively as an easily
digestible, non-irritating food (Remington et al., 1918b). Tapioca pearl makes excellent nourishment for infants about the time of weaning (Felter et al., 1898b). Certain raw starches, including corn, wheat, cassava, rice and taro root were completely digested when eaten in amounts sometimes as large as 250g (Langworthy and Deuel, 1920).

Several studies have shown that resistant starch (RS) may have important repercussions on human health (Asp et al., 1996). RS consumption has been related to reduce postprandial glycaemic and insulinemic responses, which may have beneficial implications in the management of diabetes (Granfeldt et al., 1995). Also a protective effect against colorectal cancer has been attributed to RS (Hylla et al., 1998), as well as hypocholesterolemic effects (Ranhotra et al., 1997).

Resistant starch (RS) is highest in tapioca starch when compared with colocasia, elephant yam, potato, sweet potato starch. Mahmood et al (2006) reported the tapioca starch have 7.6 ±0.13% RS by dry wt. As per categories given by Goni et al (1997) the starch containing 5-15% of RS is in high RS category. Increasing proportion of RS can help to lower the glycemic response to foods. This has potential application for management of diabetes; also the RS may have putative protective effects against colon cancer (Mahmood et al, 2006). RS also decreased serum cholesterol and triacylglycerol (Cheng and Lai, 2000), reduced fatty acid concentration in the post absorptive period (Morand et al., 1992) and increased fecal bulk (Cummings et al., 1996). RS has also been regarded as a prebiotic (Wang et al., 2002).
2.12.5.11 Legal standards of sago

According to the standards for sago laid down by the Bureau of Indian Standards in 1971, sago (Saboodana) shall mean small hard globules or pearls made from the starch obtained from the tubers of the manihot plants commonly known as cassava or tapioca (Manihot utilissima). The sago shall be white in colour. It shall be free from fermented or mushy or any other objectionable odours, added sweetening or colouring matters, adulterants, fungal contamination and insect infestation. The maximum permissible limit for sago are (g per 100 g) are: moisture 11.0; total ash (dry basis) 0.4; acid insoluble ash (dry basis) 0.10, Starch by wt. min. 98, Protein 0.3, sulfur dioxide 100 ppm, Crude fiber 0.2. The pH of aqueous extract should be 4.5-7.0. Minimum 95 per cent of sago shall pass through IS sieve 170 but retained on IS sieve 85 (BIS, 1971). The Bureau of Indian Standards in 1973 gave standards for the hygienic conditions for sago (saboodana) manufacturing units.

According to PFA rules (1985) sago shall mean small hard globules or pearls made from either the starch of the sago palm or the tubers of tapioca (Manihot utilissima) and shall be free from any extraneous matter including natural colours; total ash (dry basis) shall be maximum 0.4 per cent and ash insoluble in dilute hydrochloric acid (on dry basis) shall not exceed 0.1 per cent.

2.13 ICE CREAM MIX PROPERTIES

Like all other fluids an ice cream mix also has several characteristics. The following review only pertinent literature on
properties of the mix studied in the present experiment is presented below.

### 2.13.1 ACIDITY

The normal acidity of mix varies with the percentage of MSNF it contains. The acidity of the mix may be calculated by multiplying the percentage of MSNF by the factor 0.017 (Marshall et al., 2003). Normally acidity falls in the range of 0.119 per cent lactic acid for ice cream mix having 7 per cent MSNF to 0.221 per cent for ice cream mix having 13 per cent MSNF. A high acidity is undesirable as it contributes to excess mix viscosity, decreased whipping rate, inferior flavour, and less stable mix (Marshall et al., 2003). Drawbridge and Arbuckle (1953) studied the effect of adjusted acidity on various properties of ice cream mixed and ice cream and concluded that neutralization decreased the surface tension of the mix, improved its whipping ability and eliminated acid flavours.

### 2.13.2 VISCOSITY

A certain level of viscosity is essential for proper whipping and retention of air, and for good body and texture and richness in the ice cream. The viscosity of mix is affected by composition, processing and handling of the mix and temperature (Marshall et al., 2003). Arbuckle (1986) reported that basic viscosity of ice cream mix, which ranges from 50 to 300 mPas.

Lucas and Wilkowske (1954) concluded that greater the ageing period, the greater was the viscosity. Usacheva and Tverdokhleb (1978) studied the dependence of viscosity of the ice cream mixes on homogenization pressure, temperature and speed.
of movement of the fluid. They suggested that viscosity could be controlled by increasing the homogenization pressure and/or reducing the temperature of the mix entering the freezer.

Upadhyay et al. (1978) found that mixes containing sodium alginate had the highest initial and final viscosities and the mixes containing no stabilizer had the least. Adapa et al. (2000) delineated that application of carbohydrate based fat replacers did not enhance the elastic properties of ice cream but augment the viscosity properties.

2.13.3 WHIPPING ABILITY

Whipping ability of ice cream mix refers to the property which determines the rate at which air can be incorporated and maximum overrun can be reached when the freezing of mix is carried out (Turnbow et al., 1947).

Partial freezing of the mix results in an increased viscosity of the unfrozen portion, which gives rigidity to the lamellae making possible the retention of air.

Sommer (1951) concluded that incorporation of air in the mix in the form of small air cells and the freezing of ice cream to the proper stiffness in the freezer without sacrificing overrun are the two factors conducive to a smoother texture of the finished product. A high whipping ability can easily make both of these factors possible. Higher overruns reduced initial ice crystal sizes, whereas lower overruns had no impact on distributions because they did not affect the microstructure of the ice cream (Flores and Goff, 1999).
Jain and Verma (1969c) concluded that homogenization at 140 Kg/sq. cm. pressure and 150°F temperature gave the highest whipping ability. Pasteurization at 170°F for 10 minutes took the least time to attain 90 per cent overrun. Ageing decidedly improved the whipping ability. The stabilizer had deterring effect on whipping ability.

Upadhyay et al (1978) concluded that increase in rate of addition of stabilizers resulted in slight decrease in whipping ability.

2.13.4 COLOUR OF ICE CREAM MIX

The colour of ice cream should be attractive and pleasing. In case of plain ice cream where no external colour is used, the colour of the final ice cream is determined by colour of the mix. Huse et al. (1984) found that increasing the ratio of whey solids decreased the lightness, while increasing hydrolysis increased the lightness. In high quality ice cream the colour reminds the consumer of the ice cream flavour (Marshall et al., 2003).

2.14 MELTING CHARACTERISTICS OF ICE CREAM

Consumer desire a moderate melting resistance in ice cream, but if the ice cream approaches a condition where it does not meltdown at all, the impression on consumers is very unfavourable (Sommer, 1951).

Ice cream should slowly meltdown and produce liquid of similar appearance to the mix from which it was made (Hyde and Rothwell, 1973). Meltdown is an important factor in the enjoyment of eating ice cream because it affects eye appeal and mouths feel
and is affected significantly by fat, freezing point and overrun (Eric Flack, 1988). A high sugar content causes ice cream to melt down more rapidly, because the lower freezing point means that ice cream is less completely frozen to begin with (Sommer, 1951).

Upadhyay et al. (1978) revealed that both type and amount of stabilizer influence the resistance to melting. Lowenstein et al. (1974) concluded that in general UHT processed mix had melting resistance equal to or better than that of the batch processed mixes. Huse et al. (1984) attributed the variations in meltdown characteristics of ice cream to difficulties in controlling the overrun and drawing temperature during freezing of mix.

2.15 COST AND CALORIE OF ICE CREAM

Calories can be lowered by replacing fat with a carbohydrate based products (Gill et al., 2004). Dorp (1991) used potato starch with good gelatinization and viscosity characteristics resulted in an ice cream with 0.5 per cent fat and an energy reduction of about 30 per cent. Low calorie ice cream could be obtained by partial or complete substitution of milk fat with low calorie non-dairy ingredients (Sarkar, 2002). Anon (2006) reported that current dietary advice recommends that the bulk of our energy requirements should come from complex carbohydrates esp. starch. A number of bulking agents of low calorie, for use in ice cream are available i.e. Litesse® polydextrose (1Kcal/g), Lactitol (2 Kcal/g) and Maltodextrin (4 Kcal/g) (Larsen and Kumar, 2008).

U.S. food labeling regulations implemented in 1994 provide for a number of claims indicating a reduction in fat and calories (Anon, 2007b).
Fat Claim

- Fat-free: less than 0.5g fat/serving and /reference amount
- Low-fat: 3g or less fat/reference serving size
- Reduced or less fat: 25% or less fat/serving than regular (full fat) product
- Percent fat free: Based on 100g, when product meets the definition of low fat or a 100% fat free, claim can be made when a product meets the definition of fat free and contains no added fat

Calories

- Calorie-free: less than 5 calories/serving and /reference amount
- Low-calorie: 40 or less calories/reference serving size
- Reduced or fewer calories: 25% or less calories/serving than regular product

Substantial decline in the cost of ice cream due to substitution of dairy ingredients with non-dairy ingredients would be economically beneficial to both processors and consumers (Sarkar, 2002). Milk fat account for the nearly one third of the cost of ice cream and substitution with non dairy cheap ingredient would help substantially in reducing the cost of final product (Sarkar, 2002).
CHAPTER – 3

MATERIALS AND METHODS

This Chapter deals with the materials and methodologies employed during the present study to evaluate the suitability of sago in dietetic low fat ice cream. The various materials used during the course of investigation are encompassed hereunder. It also describes the methods which had been used for the analysis of the low fat ice cream and regular fat ice cream. All the analyses were done in duplicate and only analytical grade reagents were used in the study or otherwise as specified in the text.

3.1 INGREDIENTS/ MATERIALS

Various ingredients used for the preparation of the dietetic low fat ice cream using sago and regular fat ice cream as a control are briefly described hereunder.

3.1.1 DAIRY INGREDIENTS

The dairy ingredients used in the manufacture of the dietetic low fat ice cream and regular fat ice cream were milk, cream, skim milk and skim milk powder as the source of fat and MSNF.

3.1.1.1 Milk

Fresh, raw mixed (cow and buffalo) milk received at Anubhav Dairy of the college was used as the base material for the ice cream manufacture.

3.1.1.2 Cream and Skim milk
Whole milk was separated in an open discharge ‘Alfa Laval’ power driven mechanical cream separator, Model- C.L.O. 180520 to obtain about 40 per cent fat cream and skim milk. The cream was pasteurized at 72° C for 1 min. and cooled to about 20° C and the same was used as a source of fat in preparing the ice cream mix.

3.1.1.3 Skim milk powder

Skim milk powder of “Sagar” brand, marketed by Gujarat Cooperative Milk Marketing Federation, Anand was used in preparation of the ice cream as the source of MSNF.

3.1.2 NON DAIRY INGREDIENTS

The non dairy ingredients used in the manufacture of various categories of ice cream were cane sugar, stabilizer, emulsifier, flavourings and sago.

3.1.2.1 Cane sugar

Cane sugar used as a sweetener was of commercial grade which was obtained from the local market of Anand.

3.1.2.2 Stabilizer

Alginate S4 ice cream stabilizer of S. Square & Co., Gwalior was used as a stabilizer in the preparation of the ice cream.

3.1.2.3 Emulsifier

The emulsifier used in this study was Glycerol Mono Stearate (GMS) of Brion Fine Chem., Mumbai and was of commercial grade.
3.1.2.4 Flavourings

The different flavours used in the manufacture of various categories of ice cream were vanilla, chocolate, mango, butter, cream and combinations thereof.

(A) Vanilla

Vanilla essence No. 1 obtained from M/s Bush Boake Allen (India) Ltd., Chennai was used as the flavouring agent for the vanilla and chocolate ice cream.

(B) Chocolate

Pure cocoa powder of Blue Bird brand (Figure 3.2) obtained from United Trading Corporation, Mumbai was used as the flavouring agent for the chocolate ice cream.

(C) Mango

Haveat brand Alphanso Mango Pulp (Figure 3.2) obtained from Anand Foods and Dairy Products, Anand was used as the flavouring agent for the mango ice cream.

(D) Butter

Butter Bus Asia (Figure 3.2) supplied by Duke Thomson’s International (Indore) India was used as the flavoring agent for the butter flavour.

(E) Cream
Cream Plus supplied by Duke Thomson’s International (Indore) India was used as the flavoring agent for the cream flavour.

3.1.2.5 Sago

*Sachamoti* branded Tapioca sago (Figure 3.1) having AGMARK certification obtained from Sabu Traders, Salem, Tamilnadu was used for preparation of low fat dietetic ice cream.

3.1.2.6 Colour

Kesari powder IH 9140, Bush branded colour obtained from International Flavours and Fragrances India Ltd. was used as colouring agent in mango flavoured low fat dietetic ice cream.

3.2 PREPARATION AND PROCESSING OF SAGO

Grinding of whole sago granules, straining of sago and gelatinization of sago are required for it’s incorporation to ice cream mix. This sago preparation and processing for its use in dietetic low fat ice cream manufacture are delineated in this section.

3.2.1 GELATINIZATION

For gelatinization, sago is soaked in 3.33 times (by weight) of skimmed milk at 37°C for 10 min. Gelatinization of sago was done immediately after soaking at 85°C for 10 min. in same medium of skimmed milk by use of boiling water bath.

3.3 PREPARATION OF ICE CREAM MIX
The milk and cream used in the manufacture of the ice cream were analyzed for their composition, i.e. fat, total solids, MSNF and titratable acidity. The quantity of milk, cream, skim milk powder, sucrose, sodium alginate and GMS and other ingredients (e.g. sago, cocoa powder for chocolate ice cream, cream plus, butter buds etc.) required for a batch (i.e. 3.5 kg and 5 kg of dietetic low fat ice cream mix for home made ice cream and regular fat ice cream to be prepared in a direct expansion type batch freezer respectively) was calculated by serum point method (Sommer, 1951). The required quantities of various ingredients for each treatment were weighed, mixed and blended thoroughly. Skim milk powder and other dry ingredients (i.e. cocoa powder for chocolate ice cream) were mixed with a part of sugar and added to avoid lump formation before the temperature of the mix reached 50°C. The calculated amount of stabilizer was admixed with approximately 20 parts of sugar (by weight) and added only when the temperature of the mix reached 65°C. The mixes were further heated to 80°C. The gelatinized sago paste at temperature 80°C is mixed with such ice cream mix. The calculated amount of butter flavour and cream flavour with 10 parts of sugar is added in to mix before homogenization. The mix is homogenized in a clean and sanitized double stage high pressure homogenizer supplied by Goma (Model No. H-502, Goma Engineering Pvt. Ltd., Thane, Mumbai) at 2000 psi and 500 psi pressure in the first and second stage respectively, and again pasteurized by holding the mix at 80°C for 5 min. The pasteurized mixes were then immediately cooled to about 3-4°C and aged at this temperature for overnight. The flavouring ingredients (i.e. vanilla essence, Alphanso mango pulp)
were added immediately before freezing. Each experiment was replicated six times.

### 3.4 PREPARATION OF HOME MADE ICE CREAM

The mix (3.5 kg) was frozen in a motor driven home made ice cream freezer (Figure 3.3) having a capacity of 8 kg. The outer wooden bucket was soaked in water overnight, so as to prevent leakage of water. The metallic cylindrical vessel of the freezer and the beater cum scrapper assembly were cleaned thoroughly and subsequently sanitized with a solution of sodium hypochlorite (250 ppm chlorine). The prepared aged mix was then poured inside the cylinder till about half i.e. 3.5 kg mix. The passage surrounding the metal cylinder was filled with broken ice pieces and coarse salt (25 - 30 per cent of the ice). After assembling the freezer, the beater cum scrapper assembly was revolved with the help of the attached motor fitted to a v-belt at 100-120 rpm by switching on the motor for 10 to 15 min. till the mix was frozen to the desired consistency as sensed by an increase in the load on the motor and slippage of the belt. The freezing operation was stopped at this stage. The beater scraper assembly was then removed from the cylinder and the machine was fully covered with a clean, wet gunny bag. The ice cream thus prepared was left for 3-4 h for hardening and then served for judging. The temperature of the ice cream was recorded before serving.

Preliminary trials were conducted for selecting the level of MSNF, sugar, stabilizer and emulsifier in the experimental samples. In the preliminary trials to manufacture low fat ice cream, sugar was tried out at levels 12.5, 13 and 13.5 per cent
Sodium alginates are widely used in ice cream stabilizers because of their good water binding properties, ready dispersibility and low cost (Kilara, 1991). Sodium alginate and GMS were chosen to function at stabilizer and emulsifier respectively. Sodium alginate was tried at different levels i.e. 0.025, 0.05, 0.10, 0.15 and 0.2 per cent and GMS was also tried at different levels i.e. 0.1, 0.15 and 0.2 per cent. Since the composition of mix affects the flavour perception, preliminary trials were also conducted for the required rate of vanilla flavor, mango pulp, cocoa powder, butter bus and cream plus addition per lit. mix. The physico chemical profile and sensory characteristics of the final formulated dietetic low fat sago contained ice cream were compared with an average ice cream containing 10 per cent fat, 12.5 per cent MSNF, 13 per cent sucrose, 0.20 per cent sodium alginate (0.15 per cent sodium alginate for mango flavor) and 0.2 per cent GMS for vanilla and mango flavor, while for chocolate flavor ice cream 10 per cent fat, 12.5 per cent MSNF, 15.5 per cent sucrose, 0.15 per cent sodium alginate and 0.2 per cent GMS. Each experiment was consist of six replication and each replication consist of two treatments of low fat dietetic ice cream which is compared with regular fat (10 % fat) control ice cream.

The calorific value of the final formulated dessert was calculated on the basis of the calorie content of the ingredients used. To ascertain the commercial/ economic viability of the low fat ice cream vis-à-vis normal ice cream, the costing was carried out making necessary appropriate assumptions, wherever necessary.
3.5 FREEZING IN DIRECT EXPANSION TYPE BATCH ICE CREAM FREEZER

For preparing different batches of ice creams (control as well as experimental) in direct expansion type batch freezer (Figure 3.4), the aged mixes were frozen in a horizontal batch freezer (Pal Engg. Pvt. Ltd., Ahmedabad) with an arrangement for incorporation of air under pressure (cylinder capacity 10 lits.). The temperature of the circulating refrigerant was -23 to -30°C. After freezing the mix to a semi-solid consistency (which was 20-25 min.), as inferred from the load on the ammeter (beater load of 3 ampere) and the accumulation of ice on the freezer door, air was whipped in the frozen dessert at a constant pressure i.e. 10 psi for about 2 min. The low fat ice cream at the right stage of freezing, as ascertained from the consistency and overrun, was drawn directly into 100 ml High Impact Polystyrene (HIPS) ice cream cups and wax coated one liter paper board cartons. The surfaces of the cups were leveled and then covered with wax coated paper board lids. The temperature of the ice cream at the drawing stage was recorded. Mixes were frozen to about -4.5 to -5°C.

The filled ice cream packs were then transferred immediately to a hardening room maintained at -18 ± 2°C and hardened for 24 h. The hardened ice creams were then subjected to compositional analysis, melting quality test and organoleptic evaluation when fresh (i.e. after hardening). The final formulated dietetic low fat ice cream was also subjected to heat shock (as described in Section 3.9) and 30 days storage at -15 ± 2°C in a deep freezer. The heat shocked and stored samples were then subjected to organoleptic evaluation.
3.6 ANALYSES OF THE ICE CREAM INGREDIENTS

The various physico-chemical methodologies employed for analyzing the dairy ingredients as well as non dairy ingredients are described hereunder. The chemicals employed in the analysis were of analytical grade or otherwise as specified in the text.

3.6.1 MILK

The representative samples of milk were analyzed for the chemical parameters as described in this section.

3.6.1.1 Fat

The fat content of milk was estimated by Gerber method (ISI: 1224-Part I, 1977).

3.6.1.2 Total Solids

The total solids of milk was determined by the standard procedure using a Mojonnier Milk Tester (Model D, Mojonnier Brothers Co., Chicago, USA) according to the standard procedure described in Laboratory Manual (Laboratory Manual, 1959) using about 2 g sample.

3.6.1.3 Titratable acidity

The titratable acidity of milk was determined by the method described in the Indian Standards (ISI: 1479-Part II, 1961).

3.6.2 CREAM

The fresh cream samples were subjected to chemical analysis for fat, total solids and titratable acidity.
3.6.2.1 Fat

The fat content of cream was estimated by the Gerber method as outlined in the ISI handbook (1989) using 5 g cream.

3.6.2.2 Total solids

The total solids of cream were determined by the procedure employed for milk (Section 3.6.1.2) using 1 g sample.

3.6.2.3 Titratable acidity

The titratable acidity of cream was determined by the method described in the ISI handbook (1989).

3.6.3 SKIM MILK POWDER

The skim milk powder samples were subjected to chemical analysis for fat, total solids, titratable acidity and solubility index.

3.6.3.1 Fat

The fat content of skim milk powder was estimated by the standard procedure using a Mojonnier Milk Tester (Model D, Mojonnier Brothers Co., Chicago, USA) according to the standard procedure as described in Laboratory Manual (Laboratory Manual, 1959) using 1 g sample.

3.6.3.2 Total solids

The total solids of skim milk powder were determined by the procedure as employed for milk (Section 3.6.1.2) using 0.5 g sample.

3.6.3.3 Titratable acidity
The titratable acidity of skim milk powder was determined by the method as described in the ISI Hand Book (1989).

### 3.6.3.4 Solubility index

The solubility index of skim milk powder was determined by the standard method as described in the ISI Hand Book (1989).

### 3.6.4 SAGO

With view to ascertain the quality of sago it was analyzed for its moisture content.

#### 3.6.4.1 Moisture

The moisture content of sago was determined by the method given in ISI Hand book of Food analysis (ISI Handbook, 1989) using 2 g of sample.

### 3.7 PHYSICO-CHEMICAL ANALYSIS OF ICE CREAM MIXES

The ice cream mixes were analysed for their total solids content, fat, protein, acidity, ash, viscosity, sugars and alkaline phosphatase test.

#### 3.7.1 FAT

The fat content of the ice cream were determined by the standard method as suggested in ISI Hand Book (1989) for ice cream mixes using 5 g ice cream mix sample.

#### 3.7.2 TOTAL SOLIDS
The total solids of the ice cream were determined by the standard procedure as described for milk (Section 3.7.2.3) using 1 g of sample.

3.7.3 TITRATABLE ACIDITY

The titratable acidity of the ice cream was determined by the standard method suggested in ISI Hand Book (1989). Twenty g of sample was weighed in a 250 ml beaker. To this, 50 ml of freshly boiled and cooled distilled water was added and the contents mixed thoroughly. It was then titrated against 0.1 N sodium hydroxide using 1 ml of 1 per cent phenolphthalein as indicator, till pink colour persisted for about 15 s. The reading so obtained was converted to acidity, expressed as per cent lactic acid.

3.7.4 PROTEIN

The protein content of the ice cream mixes was determined by Kjeldahl method (AOAC, 1980). 5 g of ice cream sample was weighed accurately and transferred to a 800 ml Kjeldahl flask. 5 g of potassium sulfate, 0.1 g of copper sulphate and 20 ml of ammonia free concentrated sulphuric acid were then added to the flask and the mixture digested for about 2 h. The cooled digested mixture was diluted with 150 ml distilled water, mixed well, and after neutralizing with 50 ml of 50 per cent (w/w) sodium hydroxide it was distilled until about 150 ml of distillate was obtained. The liberated ammonia was absorbed in 50 ml of saturated boric acid solution containing 5 drops of mixed indicator (methyl red plus methylene blue). The distillate was titrated with 0.1N sulfuric acid. As per this method the total nitrogen was
determined, and the value so obtained was multiplied by a standard factor 6.38 to get the protein content.

### 3.7.5 REDUCING AND NON REDUCING SUGARS

The reducing (lactose) and non reducing (sucrose) content of the ice cream was determined using the procedure described in IS Hand Book (1989) with some modifications. 50 g of ice cream mix was weighed and volume was made to 100 ml with distilled water. After thorough mixing, 50 ml of this solution was transferred to a 250 ml volumetric flask, pH of the slurry was adjusted to 4.6 with the help of 10 per cent acetic acid drop by drop till clear precipitation of proteins occurred. The volume was then made to 250 ml with hot distilled water. After thorough mixing and 5 to 7 min. boiling, the contents were filtered through Whatman No. 42 filter paper. A part of the filtrate obtained was directly used for the estimation of reducing sugar whereas the remaining part was hydrolysed for estimation of non reducing sugars as given below.

Hydrolysis of filtrate for estimation of non reducing sugars was done in the following manner: 50 ml of the filtrate was taken in a 250 ml conical flask. To this 25 ml of 0.5 N HCl was added. The flask was then kept in boiling water bath for 1 h. The contents of the flask were cooled and the filtrate neutralized by addition of solid sodium carbonate. The contents were then transferred to a 100 ml volumetric flask and the volume was made upto 100 ml mark by addition of distilled water.

Five ml each of Fehling A and Fehling B solutions were pipette into a 250 ml conical flask. Subsequently 20 ml of distilled water and 2 to 3 pieces of porcelain were added. The content of the
flask was heated upto boiling and then the unhydrolysed filtrate from the burette was added slowly into the flask. The content of the flask was kept boiling till the end of the titration. The addition of filtrate was continued till a rust brown colour was observed. At this stage 2 to 3 dropes of methylene blue solution (0.1 per cent) was added and the colour was observed (i.e. changed to blue). Again the filtrate from burette was added till rust brown colour was obtained. The volume of filtrate used in the titration was noted. By running a parallel experiment, using standard lactose solution, a factor was calculated to find out lactose concentration in the test sample. Total reducing sugar was expressed as percentage by using a factore obtained for lactose.

Per cent total reducing sugar = \[ \frac{67.8}{\text{Titre value}} \]

The titration for non-reducing sugar necessitated filling the burette with hydrolyzed filtrate. The titration was performed in the same way as was done for reducing sugars and the reading (b) was noted. The unhydrolysed filtrate (a) was also titrated with Fehling A and B as mentioned earlier in this section to get total reducing sugar. The non reducing sugar content was determined by employing the following formula.

Non reducing sugar = \[ (0.0473/10) \times (20000/b – 10000/a) \] (per cent)

3.7.6 ASH

The ash content of ice cream samples was determined taking 3 g of the product and following the standard method described for milk (IS: 1479, Part II, 1961).

3.7.7 ALKALINE PHOSPHATASE TEST
With a view to ascertain the efficacy of heat treatment employed in processing the ice cream mix, the presence of alkaline phosphatase was qualitatively assessed by the test as described in the ISI Hand Book (1989).

3.7.8 VISCOSITY

The viscosity of the ice cream mixes was determined using a ‘Haake’ Viscosimeter (Model VT-550. Gebr, HAAKE GmbH, Germany). The equipment was standardized to system NO. 1 MV-DIN with a factor of 61.4 Pa/N-cm and M factor of 1.29 (min/s) using a speed level 10 (i.e. 500 rpm). This speed level was selected from among the speed levels 1 to 10 as the latter gave consistent results for all the products tested. The values of viscosity were recorded in m Pa.s.

First of all, sensor system (ISO 3219/DIN 53019) was fixed with rotor to the viscosimeter and the system was corrected to zero point. Next, 50 ml of the tempered sample was filled in the immersion tube and the sensor system immersed in it. The sensor system number was entered via the viscosimeter key pad and the procedure P.o. (i.e. normal mode) was selected. After starting the motor by pressing ‘start’ switch, the speed was increased from one level to the other at an interval of about 5s by selecting the speed programme. The readings for viscosity were noted from the display screen and then average value of three readings was reported.

The viscosity readings were taken after ageing mixes at 3 ± 2°C for about 24 h.

3.7.9 WHIPPING ABILITY
Whipping ability was determined by the method of Neshawy et al. (1988). This test was carried out within 2 h of addition of flavouring agent to the aged mixes. The mix was cooled to 0° C in a deep freeze in the bowl of Gopi Kitchen Machine. The mix was then agitated (for whipping) at the maximum speed and the specific volume (cubic cm/g) was determined after 0, 3 and 5 min. of whipping. The temperature of the mix was not allowed to rise above 7° C.

3.7.10 SPECIFIC GRAVITY

The specific gravity of the ice cream mixes was determined at 20° C using a specific gravity bottle according to the method described by Ling (1963).

3.8 EVALUATION OF PHYSICAL CHARACTERISTICS OF ICE CREAM

The ice cream were examined for its physical characteristics, viz., overrun, melting characteristics and hardness

3.8.1 OVERRUN

The overrun was determined as per the method given by Sommer (1951). A known volume of mix was weighed accurately (V1) and then the same volume of frozen dessert was weighed (V2) and the overrun was determined as

\[ \text{Per cent overrun} = \frac{(V1-V2)}{V2} \times 100 \]

3.8.2 MELTING CHARACTERISTICS
The method given by Loewenstein and Haddad (1972) as modified by Upadhyay et al. (1978) was employed for evaluating the ice cream for its melting characteristics. One lit. packet of ice cream from the hardening room was taken and a slice weighing 100 g was cut in duplicate. The slices were separately placed over a wire mesh screen (250 pores per sq. inch) and then placed over a long stem glass funnel of 6 inches diameter. The funnel with the wire mesh containing the ice cream slices were placed over a 100 ml glass cylinder. It was then kept in an incubator maintained at 37.5° C for 40 min. After 40 min. the volume of ice cream melted was noted. It was then weighed. The melting characteristic was determined as per cent of total ice cream melted in 40 min. at 37.5° C.

### 3.9 HEAT SHOCK TREATMENT OF ICE CREAM

The procedure suggested by Arbuckle (1986) was used to evaluate the freeze – thaw heat shock stability of frozen product samples. After 24 h of hardening, the frozen product samples were transferred to a temperature controlled area maintained at 22° C, kept for 1.5 h and then returned to the frozen stage at -18 + 2° C. Again after 24 h, the same samples were transferred once again to the same temperature controlled area for another 0.5 h shock and returned back to the frozen storage. The treatment was repeated every day for 6 days. At the end of the heat shock period, the frozen product samples were returned to the frozen storage for 24 h before being sensorily evaluated.

### 3.10 SENSORY QUALITY
The frozen product samples were tempered to -12°C for 1-2 h before serving. All the samples were coded with a 3 digit random number, and all orders of serving were completely randomized. The ice cream was subjected to sensory evaluation using a modified version of ADSA ice cream score card (Bodyfelt et al., 1988). The format of the scorecard is given in Appendix II.

3.10.1 FRESH ICE CREAM

Fresh samples of ice cream after 24 h of hardening at -18 + 2°C in hardening room were tempered at -12 + 2°C before being evaluated for organoleptic characteristics by a panel of trained judges from the faculty. The panel of judges consisted of 6 member selected on the basis of consistency in scoring of various ice cream samples. A triangle test was employed for selecting the panel members.

3.10.2 HEAT SHOCKED ICE CREAM

Sensory evaluation of such ice cream was done in a similar way as for fresh ice cream after giving heat shock treatment as described under section 3.9.

3.10.3 CONSUMER PREFERENCE TEST

In order to evaluate the consumers’ response regarding the acceptability of the sago incorporated low fat dietetic ice cream manufacture, the product was served to a large number (i.e. 80) of consumers. The samples in 100 ml HIPS cups were served to consumers who represented almost all socio-economic sections of the society.

3.11 STATISTICAL ANALYSIS
The mean values of each of the attributes under study obtained from duplicate samples of eight replications (two treatments) or four replications (four treatments) were subjected to statistical analysis using Completely Randomized Design with equal number of observations. The statistical model adopted was given by Steel and Torrie (1980) which is illustrated as given below:

\[ Y_{ij} = m + T_i + E_{ij} \]

where, \( Y_{ij} \) = Response due to \( j^{th} \) observation in the \( i^{th} \) treatment.

\( M = \) general mean

\( T_i = \) effect of \( i^{th} \) treatment, and

\( E_{ij} = \) Error due to \( j^{th} \) observation in the \( i^{th} \) treatment.
CHAPTER – 4

RESULTS AND DISCUSSION

There is an old saying: Health is Wealth. In recent times of globalization, the average Indian has never had it so good. Affluence and globalization has made a different life style for them. Paradoxically, a nation with 20 per cent of the poor of the world is facing an obesity crisis. According to WHO, the obesity epidemic is increasing faster in the developing countries than in the developed world. Being overweight puts a person at greater risk of developing high blood pressure, cardiac diseases, diabetes, some cancers and other health risks (Purie, 2006). Indian ranks among top 10 obese nations of the world and it has been reported that 120 millions of urban Indians are seriously obese (AIIMS, 2005). Hence, it can be said that an average Indian is in danger of losing the greatest gift of all: good health.

In recent years low fat, low calorie, reduced calorie, diabetic and dietetic foods have become increasingly popular in all segments of the society. The words of Hippocrates, “Let food be your medicine and medicine be your food” holds true in the current day context too. The successful development of good quality dietetic food would depend to a large extent on the imitation and simulation of organoleptic properties of the equivalent standard products. The present study was undertaken to evaluate the suitability of sago as a
natural, healthful bulking and fat replacer ingredient in dietetic low fat ice cream.

However, no reports are available in the literature regarding use of sago in manufacture of low or full fat versions of ice cream. Therefore, present project has been contemplated with the following objectives.

(i) To study the gelatinization of sago starch
(ii) Incorporation of gelatinized sago in low fat ice cream
(iii) Evaluation of the low fat ice cream containing sago for its physico-chemical, rheological and sensory characteristics
(iv) Evaluate use of creamplus and butterbud to improve the richness of low fat ice creams.
(v) Comparison of such dietetic ice cream with full fat ice cream even on commercial trial on batch freezers.
(vi) Cost effectiveness and calorie contributions of experimental ice cream as against full fat control ice cream.

The average composition and titratable acidity of various dairy ingredients viz. mixed milk, cream, skimmed milk, and skimmed milk powder used in the manufacture of the control and experimental mixes are given in Appendix I. All the ice cream mixes showed negative alkaline phosphatase test indicating that the mixes were pasteurized adequately.

The basic three varieties of ice cream are plain ice cream, chocolate ice cream and fruit & nut ice cream. One flavour from each...
category was selected viz. Vanilla, Chocolate and Mango. The data obtained during this investigation were statistically analyzed using Completely Randomized Design.

4.1 FORMULATION OF SAGO BASED LOW FAT ICE CREAM

Preliminary trials were conducted to select the level of sago, form of sago, medium for sago gelatinization and condition for gelatinization, quantity of medium of gelatinization, MSNF, sugar and stabilizer quantity, rate of different flavouring (vanilla, cocoa powder, mango pulp, creamplus, butterbuds) and colouring. All the preliminary trials were performed by preparing home made ice cream using “salt and ice” freezer. The drawing temperatures of all the ice creams were in the range of -4°C to -5°C.

For formulating low fat ice cream using sago preliminary trials were conducted first for selecting the level of main constituents for ice cream i.e. fat, MSNF, sucrose, stabilizer and emulsifier, and the functional ingredient sago. Fat contributes 9 Kcal/g to food products, whereas, proteins and carbohydrates contribute only 4 Kcal/g each. This means that a standard 10 per cent fat ice cream contains approximately 200 Kcal/100g. A reduction in the calorie content was achieved by reducing the fat content. Apart from functioning as energy source, fat also provides several functional and organoleptic properties to ice cream. In order to obtain a good quality low fat ice cream, the proper selection of raw material and adjustment of the formulation concerned are of utmost importance. Reduced calorie ice cream mixes have low total solids compared to standard products.
(about 30-35 per cent TS as against of 38-40 per cent in control), which means that they make considerable demand on the functional ingredients (e.g. fat replacers, bulking agents, stabilizers). The low fat ice creams were made employing a motor driven mechanized home made ice cream freezer (section 3.4).

4.1.1 MILK FAT AND MSNF LEVELS

The milk fat contributes to the rich and creamy flavour and texture of ice cream (Berger, 1997). Milk fat influences the texture of ice cream by mechanically obstructing ice crystal growth (Marshall and Arbuckle, 1996). The presence of milk fat affects the sensory evaluation by causing a lubricating sensation in the mouth (Keeney, 1979; Arbuckle, 1986).

The milk fat in ice cream normally ranges from 2.5 to 14.0 per cent (Hamilton, 1990). Reduction in fat content from 10.0 to 2.5 per cent resulted in loss of creaminess, which is otherwise enjoyed by consumers (Morris, 1992). According to PFA rules (1955) as amended on 7th June 2005, low fat ice cream should have maximum 2.5 per cent fat. So looking to the mandatory standards it was decided to use 2.4 per cent fat level in low fat ice cream.

The proper amount of MSNF not only helps in producing a desirable body, but also increases the viscosity and resistance to melting. The proteins in MSNF help to make the ice cream smoother, compact and thus tend to prevent weak body and coarse texture.
The MSNF content of ice cream varies inversely with the fat content. The level of MSNF was varied in the formulation of ice cream to see its impact on the sensory properties of low fat ice cream. The MSNF content tried out were 13.5, 14.0 and 14.5 per cent (w/w) in ice cream. The tentative levels of fat as well as MSNF was based on the preliminary investigations and reported literature (Garcia et al., 1995; Kebary and Hussein, 1997; Marshall et al., 2003). Ice cream having 13.5 per cent MSNF was weak bodied. The ice cream having 14.5 per cent MSNF had powdery taste. Low fat ice cream with 14.0 per cent MSNF give desirable body and texture, without imparting pronounced powdery taste.

Hence, a level of 2.4 per cent fat and 14.0 per cent MSNF was chosen in the tentative formulation.

4.1.2 LEVEL OF SUCROSE

To have desired sweetness in regular 10 per cent fat ice cream the level of sucrose required ranges from 13 to 16 per cent. The main function of sweeteners is to increase acceptance of the product by making it sweet and by enhancing the pleasing flavour of ice cream. Sweetness depends on the concentration of sugar in water of the mix; thus decreasing the water of the mix is equivalent to increasing the sweetness and vice versa (Marshall et al., 2003). It is also reported that fat content affects the perceived sweetness intensity of sweeteners (Weit et al., 1993). Ice cream containing 0.5 per cent milk fat was significantly sweeter than ice creams containing 4, 6 and 9 per cent milk fat (Prindiville et al., 1999, 2000).
During preliminary screening the sweetness of sucrose was found to increase as fat content of ice cream decreased. Therefore to select the level of sucrose in the preliminary screening, sucrose was used at the rate of 12.5, 13.0 and 13.5 per cent (w/w) in the formulation of the low fat ice cream. For obtaining a frozen product with optimum sweetness it was found necessary to add sucrose at the rate of 13.0 per cent.

Hence, a level of 13.0 per cent sucrose was chosen in the tentative formulation.

**4.1.3 TYPE OF GELATINIZATION MEDIUM AND ITS QUANTITY**

Water has been the medium used for gelatinization of starch. But few researchers have worked on milk as a medium for gelatinization. Abu-Jdayil et al (2004a) and Jdayil et al (2004b) studied the starch-milk heating systems. Based on their study we selected skim milk as gelatinization medium.

Use of water as medium for gelatinization of sago may create problem of dilution of ice cream and would required use of higher content of concentrated source of MSNF. So in present study skim milk was tried as gelatinization medium for starches in preliminary trials and found it suitable.

For quantity of medium we took different trials of gelatinization. For 300 g sago we took 600 g, 800g, 1000g and 1200g of skim milk. The one prepared with 1000 g of skim milk showed good gel characteristics. Quantity lower than 1000 g of skim milk
resulted in too sticky gel, which was difficult to handle and incorporate into mix. More than 1000 g of skim milk gave some what weaker gel. Therefore, level of 1000g skim milk per 300g of sago was selected for gelatinization.

4.1.4 LEVEL OF SAGO

Sago contains 98 per cent starch. Sago has GRAS status being of natural origin. The maximum level of starch is 30 g per Kg of ice cream as per PFA (2006). We selected three levels of sago for addition in low fat ice cream i.e. 1, 2 and 3 per cent. The maximum level of sago i.e. 3 per cent gave slight weak and watery body to ice cream. The maximum permissible limit of starch as sago was selected for use in low fat ice cream.

The suboptimal viscosity and mouth-feel of low fat ice cream containing sago alone can be adjusted by addition of suitable stabilizer.

4.1.5 TYPE AND LEVEL OF STABILIZER

It was decided to use a stabilizer of natural origin. From amongst the stabilizers of natural origin (gelatin, alginate, gums, pectin), alginate was selected because of its good water binding properties, ready dispersibility and low cost (Kilara, 1991 a). It is reported to contribute short texture, good melting properties and adequate storage stability (Andreasen and Nielsen, 1998). The cost of sodium alginate used in this study was Rs.160 / kg. Moorthy and Balachandran (1994) recommended the use of sodium alginate in
low fat (6 per cent) ice cream compared to combination of i.e. isabgul husk: guar gum (70:30) since the former gave small sized ice crystals. Therefore, it was decided to use sodium alginate as a stabilizer.

In dairy products containing starch and stabilizer, the requirement of stabilizer is less since the starch also complements the function of stabilizer (Verbeken et al., 2004). Based on preliminary trials it was decided to use sodium alginate at 0.05 per cent level. Higher level of usage of sodium alginate gave more viscous mix which resulted in heavy bodied, gummy, pasty, sticky frozen product. On the other hand levels lower than 0.05 per cent gave week bodied product that melted at unusually faster rate.

It is generally believed that the main functions of stabilizers in ice cream are to limit the size of ice crystals, to provide protection against heat shock and to promote dryness. In the formulation of low fat (6% fat) frozen dessert a stabilizer-emulsifier blend (Cremodan SE) has been incorporated at 0.7 per cent level (Abdou et al., 1996) whereas in another low fat ice cream formulation (0.1 and 1.6 per cent fat). Stabilizer-emulsifier blend (T8006) comprising of cellulose gum, guar gum carageenan, mono- and di-glycerides, and sodium hexametaphosphate at the rate of 0.2 per cent (Roland et al., 1999b). On the basis of preliminary trials a level of 0.05 per cent sodium alginate was chosen to complement sago starch as stabilizer in the ice cream formulation.

4.1.6 TYPE AND LEVEL OF EMULSIFIER
The low fat ice cream prepared in preliminary trials without use of emulsifier showed a less whipping ability. Emulsifiers control fat agglomeration and coalescence, facilitate air incorporation, impart dryness at extrusion, smooth texture and consistency, resistance against shrinkage and improve melting properties (Bhandari, 2001; Marshall et al., 2003). Emulsifiers increased the consistency or viscosity of low fat ice cream mix and reduced whipping times and ice crystal size. They also imparted greater stability to heat shock (Baer et al., 1997).

The emulsifiers used in ice cream are primarily mono- and di-glycerides and sorbitan esters, especially polyoxyethylene sorbitan monooleate (Polysorbate 80) (Marshall et al., 2003). The preferred emulsifier is Glycerol monostearate (GMS), which is used at levels ranging from 0.20 to 0.25 per cent. Generally speaking, the lower the fat, the higher the monoglyceride required. The recommended concentration of mono- and di-glycerides with 60 per cent α-mono content was 0.5 and 0.6 per cent for 3 per cent fat and 0 per cent fat frozen dessert respectively (Marshall et al., 2003).

Based on preliminary trials, it was decided to use GMS at the rate of 0.20 per cent in the formulation. Higher levels viz. 0.25, 0.30 did not show any significant improvement in the quality of the product whereas at levels less than 0.20 per cent viz. 0.1, 0.15 gave a product which was slightly coarser in texture. Hence, a level of 0.20 per cent GMS was chosen in the ice cream formulation.
From the experimentation carried out, the following formulation (Table 4.1) was tentatively chosen and used for further screening and deciding the level of ingredients.

**Table 4.1: Tentative formulation of a low fat experimental and control ice cream**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Constituents</th>
<th>Per cent level of addition</th>
<th>Sago containing low fat ice cream</th>
<th>Regular fat control ice cream</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Milk Fat</td>
<td>2.4</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>MSNF</td>
<td>14.0</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Sweetener (sucrose)</td>
<td>13.0</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Stabilizer (sodium alginate)</td>
<td>0.05</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Emulsifier (GMS)</td>
<td>0.2</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Sago</td>
<td>3.0</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total solids</td>
<td>32.65</td>
<td>36.00</td>
<td></td>
</tr>
</tbody>
</table>

4.1.7 **FLAVOURINGS**

The low fat ice cream lacked in richness and creaminess which could not be tackled by even increasing the flavouring level of vanilla. To give a flavour of fat in such low fat ice cream we tried out the butterbuds and creamplus.
The level of creamplus flavouring tried out were viz. 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 per cent in ice cream mix. Based on the flavour of ice cream found suitable using a given level of creamplus it was further investigated at three levels viz. 0.15, 0.20, and 0.25 per cent.

Likewise, butterbuds flavouring was tried out in ice cream mix at i.e. 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 per cent levels. After primary selection the level of butterbuds flavouring tried out in ice cream trials were 0.025, 0.05, 0.075, 0.10 and 0.15 percent.

From such trial a level of 0.2 per cent for creamplus flavour and 0.05 per cent of butterbuds flavour was finally selected.

Initially 'home made ice cream' was prepared using the various flavour combinations in sago containing low fat ice cream and chemical composition, physical properties and sensory attributes of experimental ice cream were evaluated along with a control ice cream with 10.0 percent fat.

In the last part of the study, the most sensorily preferred low fat ice cream was selected and flavourings at such levels were tested in industrial trial by freezing mix in direct expansion type batch freezer for knowing their commercial feasibility.

4.2 COMPARATIVE APPRAISAL OF LOW FAT WITH CONTROL ICE CREAM

In this section, the physico-chemical and sensory characteristics of the low fat sago containing ice cream (2-4 per cent fat) was made and compared against a good average 10 per cent fat
Three different flavours viz. vanilla, chocolate and mango were tried out as flavourings in low fat as well as full fat ice creams.

### 4.2.1 LOW FAT VANILLA ICE CREAM CONTAINING SAGO

The tentative formulation (table 4.1) for low fat ice cream using sago was tried out with vanilla flavouring. Two variants of low fat vanilla ice creams were prepared; one using creamplus (0.2 per cent) and other using butterbuds (0.05 per cent). These two low fat ice creams were compared with full fat vanilla ice cream. Totally six replications were under taken. The results of experimentation are discussed under three main categories: chemical composition, physical properties and sensory evaluation. Table 4.2 shows formulation for vanilla flavoured low and regular fat ice cream.

#### Table 4.2: Formulation of a low and full fat vanilla ice cream

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Constituents</th>
<th>Per cent level of addition</th>
<th>Sago containing low fat ice cream</th>
<th>Regular fat control ice cream</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Milk Fat</td>
<td>2.4</td>
<td></td>
<td>10.5</td>
</tr>
<tr>
<td>2.</td>
<td>MSNF</td>
<td>14.0</td>
<td></td>
<td>12.5</td>
</tr>
<tr>
<td>3.</td>
<td>Sucrose</td>
<td>13.0</td>
<td></td>
<td>13.0</td>
</tr>
<tr>
<td>4.</td>
<td>Sodium alginate</td>
<td>0.05</td>
<td></td>
<td>0.20</td>
</tr>
<tr>
<td>5.</td>
<td>GMS</td>
<td>0.2</td>
<td></td>
<td>0.20</td>
</tr>
<tr>
<td>6.</td>
<td>Sago</td>
<td>3.0</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>7.</td>
<td>Vanilla flavour</td>
<td>0.08</td>
<td></td>
<td>0.08</td>
</tr>
<tr>
<td>8.</td>
<td>CreamPlus/ButterBuds</td>
<td>0.20/0.05</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>
4.2.1.1 Chemical composition

Table 4.2.1.1 shows the average values of compositional parameters viz. fat, protein, reducing and non-reducing sugars, and total solids of control and sago containing low fat vanilla ice creams.

**Table 4.3: Chemical composition of vanilla ice cream**

<table>
<thead>
<tr>
<th>Type of Ice creams</th>
<th>Constituents (per cent)</th>
<th>Fat</th>
<th>Protein</th>
<th>Reducing sugars</th>
<th>Non-reducing sugars</th>
<th>Total solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td></td>
<td>10.23</td>
<td>4.61</td>
<td>7.16</td>
<td>12.91</td>
<td>36.19</td>
</tr>
<tr>
<td>T1</td>
<td></td>
<td>2.38</td>
<td>5.14</td>
<td>7.95</td>
<td>12.87</td>
<td>32.75</td>
</tr>
<tr>
<td>T2</td>
<td></td>
<td>2.38</td>
<td>5.16</td>
<td>7.96</td>
<td>12.89</td>
<td>32.78</td>
</tr>
</tbody>
</table>

Statistical analysis

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>0.05</th>
<th>0.026</th>
<th>0.013</th>
<th>0.136</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD(0.05)</td>
<td>0.181</td>
<td>0.151</td>
<td>0.077</td>
<td>NS</td>
<td>0.411</td>
</tr>
<tr>
<td>C.V.%</td>
<td>2.95</td>
<td>2.46</td>
<td>0.81</td>
<td>0.24</td>
<td>0.99</td>
</tr>
</tbody>
</table>

T1: Creamplus and sago containing low fat experimental ice cream

T2: Butterbuds and sago containing low fat experimental ice cream

C: Regular fat ice cream

*Results and discussion*
The average value for fat of control ice cream was 10.23 and for low fat ice cream it was 2.38 (Table 4.3). The low fat ice cream had significantly lower fat than control ice cream. The low fat and normal average fat ice creams conformed to the PFA requirements.

The average value of protein in control ice cream was 4.61 while low fat cream plus containing (T1) ice cream had 5.14 and for butterbuds (T2) ice cream the value was 5.16. The low fat ice creams had significantly higher protein content compared with control. The high protein content is due to high MSNF content (14.0 vs. 12.5 percent) kept in low fat ice cream. The values of protein content in all the ice creams were well above the minimum prescribed for ice cream by PFA.

The average values of reducing and non-reducing sugar for all the ice creams are shown in Table 4.3. It is seen from table that the reducing sugars of low fat ice cream are significantly higher than those of control ice cream. The low fat ice cream had higher MSNF then their full fat counterpart. Due to higher MSNF, the lactose content which represents the reducing sugar of ice cream mix was also higher compared to control.

Non-reducing sugar content of low fat ice cream was not significantly different from that of control ice cream.

Low fat ice cream has significantly ($p < 0.05$) lower total solids content. Total solid content of low fat ice cream and average fat ice cream were as per the PFA specifications laid down for the two types of ice cream.
The compositional attributes are well above the minimum values specified for normal ice cream and low fat ice cream as laid down by PFA (2006).

4.2.1.2 Physical properties:

Table 4.4 shows the average values of physical parameters viz. acidity, viscosity, overrun and melting resistance of control and low fat vanilla ice creams.

<table>
<thead>
<tr>
<th>Type of Ice cream</th>
<th>Acidity (% LA)</th>
<th>Viscosity (mPas)</th>
<th>Overrun (%)</th>
<th>Melting resistance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.212</td>
<td>71.33</td>
<td>56.05</td>
<td>52.56</td>
</tr>
<tr>
<td>T1</td>
<td>0.222</td>
<td>86.33</td>
<td>52.64</td>
<td>44.34</td>
</tr>
<tr>
<td>T2</td>
<td>0.221</td>
<td>85.17</td>
<td>53.1</td>
<td>44.99</td>
</tr>
</tbody>
</table>

Statistical analysis

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>CD(0.05)</th>
<th>C.V.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidity</td>
<td>0.002</td>
<td>0.007</td>
<td>2.78</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1.38</td>
<td>4.16</td>
<td>4.18</td>
</tr>
<tr>
<td>Overrun</td>
<td>1.261</td>
<td>NS</td>
<td>5.73</td>
</tr>
<tr>
<td>Melting</td>
<td>0.97</td>
<td>2.92</td>
<td>5.02</td>
</tr>
<tr>
<td>resistance</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* g of ice cream melted at 37.5°C for 40 min.

T1: Creamplus and sago containing low fat experimental ice cream

T2: Butterbuds and sago containing low fat experimental ice cream

C: Regular fat ice cream
The average value of acidity for control ice cream mix was 0.212 per cent LA, which was significantly lower than that of experimental mixes T1 and T2 which had acidity value 0.222 and 0.221 respectively. The higher acidity of experimental mixes could be ascribed to higher MSNF content in experimental ice cream mixes. The minor variations in compositional attributes including titratable acidity do occur in commercial practice of ice cream making and could be regarded as normal.

The values of acidity observed in present study are similar to the ones reported by Tracy and Hahn (1938), Gabriel *et al* (1986), Neshawy *et al* (1988) and Rahman (1991).

The control mix had the least viscosity after ageing (71.33 mPas). The viscosity of experimental mixes T1 and T2 was higher i.e. 86.33 and 85.17 mPas respectively. Such increase in viscosity was found to be significant.

Viscosity of ice cream mix is a complex property and has been found to be affected by a number of factors, viz. composition, kind and quality of ingredients, processing and handling of mix, concentration (total solids), temperature etc.

The higher viscosity of the mixes made using sago could be ascribed to the higher MSNF content reflecting on higher protein content which has water-binding characteristics. In addition, use of gelatinized starch complemented with low level of sodium alginate helped in better hydration property which reflected in higher viscosity in such experimental mixes. Schmidt *et al*. (1993) found that the use
of carbohydrate-based fat replacers in reduced fat ice creams resulted in mixes with higher viscosity.

Part of the skim milk used in preparation of experimental mixes got high heat treatment during the process of gelatinization, might influence the viscosity of low fat ice cream mixes. Williams (1929) reported that ice cream mix made using skim milk powder prepared from milk preheated at 83°C for 30 min had a higher viscosity than skim milk powder made from milk preheated at 63°C. Eric Flack (1988) reported that denatured proteins have much greater water binding capacities, which could increase the viscosity of experimental ice cream. Turnbow et al (1947) reported that precipitation of calcium by heat is beneficial to protein hydration.

A high viscosity was believed to be essential at one time, but for fast freezing and rapid whipping in a modern equipment a lower viscosity seems desirable (Arbuckle, 1977). Sommer (1951) and Arbuckle (1977) have reported viscosity of ice cream mixes to range from 50-300 cp.

The sago used in the low fat experimental ice cream had 86-88 per cent starch. This hydration property of starch might be responsible for the higher viscosity values observed. The starch contained in potato pulp led to increased viscosity of ice cream mixes containing added potato pulp; the starch being a hydrocolloid (Das et al, 1989). Cottrell et al (1980) also indicated that polysaccharides such as starch increased the mix viscosity and restricted ice crystal growth during storage of ice cream. Viscosity building has been cited
as a general function of carbohydrate-based fat replacers (Akoh, 1998).

The acidity of ice cream mix also affects the viscosity of ice cream mixes (Arbuckle, 1977). During gelatinization of starch there might be inter and intra molecular reactions of milk constituents and sago constituents, which may play some role in increasing viscosity of ice cream mixes (Yue Li et al., 2008).

The overrun of ice cream is an important property because of their relation to quality of ice cream and profit. It also affects the body, texture and palatability of the final product. The overrun in ice cream is affected by the composition of ice cream mix, ingredients used especially surfactants/emulsifiers, history and processing of the mix, and the freezing process. Hence, overrun of experimental low fat sago containing ice cream and control ice cream were monitored.

Table 4.4 depicts the average value of overrun of ice cream. The table shows that the overrun of control ice cream was marginally higher than that of low fat ice creams; however such effect was statistically non significant.

The viscosity of mix affects the whipping ability of mixes (Arbuckle, 1977). It can be stated that differences in whipping ability resulted in overrun of mixes could be due to the differences in the viscosity (section 4.2.1.2.) of low and full fat mixes after ageing.

The slight lower overrun encountered in the experimental samples may be ascribed to the relatively higher viscosity associated
with such samples. The results obtained during the present investigation corroborates with that of Das et al. (1989) who found that the rise in viscosity of ice cream mixes containing potato pulp was responsible for the adverse effect on overrun in ice cream.

The data presented in Table 4.4 are average of ice cream (g/100g ice cream) melted in 40 min at 37.5°C. It is evident from the tabulated results that the control ice cream had lower melting resistance as reflected from the higher quantity of ice cream melted under the test conditions. The melting resistance of sago containing low fat ice cream was significantly greater than that of control ice cream. However, both the experimental samples had statistically similar melting resistance.

Melting of an ice cream is an important factor in the enjoyment of eating of ice cream. Upon melting ice cream should not melt quickly and upon melting, it should melt to a nice smooth creamy consistency. Melting of ice cream is important from at least two main points of view, one is eye appeal and second is mouth feel; which may differ according to the type of ice cream (Flack, 1988).

There are number of factors which may influence the melting properties of ice cream. These include raw materials, fat, milk solids, sugars, emulsifier and stabilizer and processing conditions, such as pasteurization, homogenization, ageing, freezing, hardening and overrun (Flack, 1988). Muse and Hartel (2004) reported that fat destabilization, ice crystal size and the consistency coefficient of the mix were found to affect the melting rate of ice cream. They
concluded that the freezing point and drawing temperature of ice cream would decide the ice crystal size in the resultant ice cream which could influence the meltdown property of ice cream. The slower meltdown for experimental ice cream as compared to control could have been as a result of greater stabilization of ice cream exerted by combination of sago and sodium alginate.

In general, as the viscosity increases the resistance to melting and smoothness of ice cream increases (Arbuckle, 1977). The increase in the viscosity of ice cream mixes containing sago in low fat ice cream is clearly obvious from Table 4.4. Das et al (1989) also observed such phenomenon when used potato pulp (starch) in ice cream.

Slow melting generally indicates over stabilization and such condition can be corrected by reducing the amount of stabilizer and/or emulsifier. Sago contains hydrocolloids. This might be responsible for increasing the melting resistance of sago containing low fat ice cream.

Guinard et al. (1997) reported that fat content and even a partial replacement of fat by fat substitutes most likely affects the perceived rate of melting of different foods. Hyvonen et al. (2003) reported that higher fat content in ice cream seems to retard melting. Conversely Frost et al. (2005) reported that an increase in fat level increased the melting rate.

Guinard et al. (1997) reported that no relationship between the instrumental and sensory melting rates, perhaps due to different
melting environment in the measurements. Li et al. (1997) in contradiction reported that melting rate increased as fat content increased, when measured physically of the per cent weight melted. Increasing fat content increased physical melting rate, when sensory meltability of ice cream decreased (Roland et al., 1999b).

### 4.2.1.3 Sensory quality

Table 4.5 shows the average values of sensory parameters viz. flavour, body and texture, melting quality, colour and appearance, and total sensory quality of control and low fat vanilla ice creams. The sensory quality of the ice cream samples were adjudged by a panel of 6 judges using the score card recommended by Arbuckle (1977). The maximum score allotted were 45, 30, 5, 5 and 100 for flavour, body and texture, melting quality, colour and appearance, and total sensory quality respectively.

It is evident from the tabulated values that fresh experimental ice creams made using sago and creamplus is equivalent to control ice cream in terms of flavour score. The experimental ice cream prepared with sago and butterbuds however statistically had lower flavour score when compared with control. The experimental low fat ice cream having creamplus was preferentially liked by judges, when compared with butterbuds containing low fat ice cream.

Jobling (2004) reported that tapioca starch had a bland taste which has advantages in many delicately flavoured food applications.
Goubet et al. (1998) reported that retention and release of aroma compounds from food matrices is largely governed by the physico-chemical properties of the aroma compound and by specific interactions between aroma compounds and food compounds.

Table 4.5: SENSORY QUALITY OF VANILLA ICE CREAM

<table>
<thead>
<tr>
<th>Type of ice cream</th>
<th>Sensory score for</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flavour</td>
<td>Body &amp; texture</td>
<td>Melting quality</td>
<td>Colour and appearance</td>
<td>Total sensory quality</td>
</tr>
<tr>
<td>C</td>
<td>37.28</td>
<td>27.28</td>
<td>4.002</td>
<td>3.99</td>
<td>87.55</td>
</tr>
<tr>
<td>T1</td>
<td>37.37</td>
<td>27.25</td>
<td>4.078</td>
<td>4.36</td>
<td>88.05</td>
</tr>
<tr>
<td>T2</td>
<td>35.30</td>
<td>27.08</td>
<td>4.083</td>
<td>4.31</td>
<td>85.78</td>
</tr>
</tbody>
</table>

Statistical analysis

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>0.292</th>
<th>0.099</th>
<th>0.132</th>
<th>0.462</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD(0.05)</td>
<td>1.38</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>1.39</td>
</tr>
<tr>
<td>C.V.%</td>
<td>3.07</td>
<td>2.63</td>
<td>5.99</td>
<td>7.68</td>
<td>1.3</td>
</tr>
</tbody>
</table>

C: Regular fat ice cream

T1: Creamplus and sago containing low fat experimental ice cream

T2: Butterbuds and sago containing low fat experimental ice cream

Hyvonen et al. (2003) reported that flavour release is least in 18 per cent fat ice cream and highest in fat-free ice cream. Fat of ice cream retarded the flavour release. The changes in the amount of fat
in food affected the perceived intensity and duration of flavour. (Shamil et al., 1991/92, 2005).

Tietz et al. (2008) reported that head space intensity of starch-aroma systems was slightly reduced due to starch-aroma interactions compared to aroma–water interactions. Starch and other hydrocolloids have been shown to interact with flavour compounds by binding them (Hau et al., 1996).

Roland et al. (1999a) and Li et al. (1997) reported that differences in fat content (0 to 10 per cent) had no effect on the perception of sweetness of ice cream. Ohmes et al. (1998) emphasized the importance of fat as a flavour modifier in delicately flavoured ice cream like vanilla.

In terms of body and texture there are non significant difference between sago contained two experimental samples and control. Likewise both sago containing ice creams irrespective of presence of creamplus and butterbuds had similar body and texture score. Sago was found to increase the viscosity of ice cream mix significantly, as has been delineated and discussed earlier in section 4.2.1.2., which might have been responsible for improving the body of low fat ice creams in spite of having low TS (about 3.0 per cent less compared to control).

Richardson et al. (1993) concluded that the sensation of creaminess is the combination of small fat droplets and an adequately high viscosity. To be perceived as creamy, a smooth but viscous fluid layer is needed between the tongue and palate. It has
been proposed that the ability of carbohydrate based fat replacers to effectively mimic the physical properties of milk fat will be determined by the colloidal properties of the carbohydrate involved and their impact on mouth feel (Specter and Setser, 1994).

Hyvonen et al. (2003) concluded that carbohydrate may cause a similar mouth feel as fat does which justifies the use of carbohydrates as fat substitutes in reduced fat dairy products. Aime et al. (2001) reported that modified pea starch used in reduced fat vanilla ice cream was effective in mimicking the firmness of ice cream with higher fat content. However, use of modified starches in ice cream with less than 5 per cent milk fat does not result in as much smoothness or creaminess as observed in regular fat ice cream.

The sago containing low fat vanilla ice cream had the same melting characteristics as normal (10 per cent) fat ice cream (Figure 4.1). The melting quality of control and experimental low fat ice cream was statistically at par.

The experimental samples generally yielded as viscous melting as given by control. The hydrocolloid inherent in sago might have been beneficial in this regard. The experimental sample had low total solids compare to control even then they exhibited melting quality comparable to control ice cream. Likewise the melting quality of two experimental low fat ice creams was also identical.

Roland et al. (1999) reported that melting time and ice cream hardness were not significantly different for ones having 0.1, 3 and 7
per cent fat, but these characteristics of low fat ice creams differed significantly from those of the 10 per cent fat ice cream.

In case of colour scores, the experimental ice cream had marginally superior colour and appearance score over control however, the difference was non-significant.

The colour of experimental samples were clean white, while the colour of control ice cream was slight off white having yellowish tinge (Figure 4.2). The off white colour of control ice cream might be due to high fat content (10 per cent), fat is yellowish in colour especially ones having β-carotene pigment. Roland (1999a) reported that as the fat per cent of ice cream increases from 0.1 to 10 per cent, the yellowness of ice cream increases.

The average total sensory score of low fat ice cream and control ice cream are tabulated in Table 4.5. It is seen from the table that the total sensory score of low fat vanilla ice cream containing creamplus and vanilla flavour had significantly higher value than that of control ice cream and low fat ice cream containing butterbuds plus vanilla; sample T2 had the least total sensory score which differed significantly only from control. The total sensory score of the ice creams showed that all the ice creams had acceptable sensory quality.

From the findings presented in Table 4.5 it could be concluded that use of sago in low fat ice cream containing creamplus with vanilla had as good sensory attributes as 10 per cent fat control ice cream with regard to flavour, body and texture, melting quality.
colour and appearance, and total sensory score. However butterbuds containing low fat ice cream had significantly lower flavour and total sensory scores than control ice cream.

It could be concluded that sago served as a functional ingredient in low fat vanilla ice cream using creamplus as flavour enhancer. Such ice cream was comparable to normal fat ice cream in terms of body and texture, melting characteristics, and colour and appearance.

**4.2.2 LOW FAT CHOCOLATE ICE CREAM CONTAINING SAGO**

The influence of sago functional ingredient was also evaluated in chocolate ice cream. Low fat chocolate ice cream was prepared using creamplus and butterbuds flavourings to improve upon the flavour. These two low fat chocolate ice creams were compared with normal fat chocolate ice cream. Totally six replications were undertaken.

The level of cocoa powder used for chocolate ice cream was selected based on preliminary trials, from amongst 1.5, 2.0, 2.5 and 3.0 per cent level of cocoa powder. The cocoa powder is inherently bitter and hence chocolate ice cream requires more sweeteners than do most other varieties (Prindiville et al, 1999). The cocoa powder contributes further to the total solids of ice cream and higher sweetener level also raised the TS content. Increase in total solids leads to increase viscosity of ice cream mix, hence to control the viscosity it is desirable to reduce the quantity of stabilizer to be used. Trials were taken to select the level of stabilizer for chocolate ice
cream. Vanilla flavour is reported to enhance the chocolate flavour in chocolate ice cream. The cocoa powder also contribute to the total fat hence, 2.0 per cent milk fat was deliberately kept in chocolate ice cream. Likewise sago was used here at 2.5 per cent level as against 3.0 per cent used in vanilla ice creams. After necessary modification, the chocolate ice cream formulation is shown in Table 4.6

Table 4.6: Formulation for low fat and full fat chocolate ice creams

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Constituents</th>
<th>Chocolate ice creams</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low fat</td>
<td>Full fat</td>
</tr>
<tr>
<td>1</td>
<td>Milk Fat</td>
<td>2.0</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>MSNF</td>
<td>14.0</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sucrose</td>
<td>15.5</td>
<td>15.5</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Sodium Alginate</td>
<td>0.025</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>GMS</td>
<td>0.20</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sago</td>
<td>2.5</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Cocoa powder</td>
<td>2.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Vanilla flavour</td>
<td>0.04</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Creamplus/Butterbuds</td>
<td>0.2/0.05</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Total solids</td>
<td>36.43/36.28</td>
<td>40.35</td>
<td></td>
</tr>
</tbody>
</table>
4.2.2.1 Chemical composition

Table 4.7 shows the average values of compositional parameters viz. fat, protein, reducing and non-reducing sugars, and total solids of control and low fat chocolate ice creams prepared using sago with butterbuds and creamplus as applicable.

The average values for the fat of control ice cream was 10.18 and for low fat ice creams it was 2.07 as shown in Table 4.7. The low fat ice cream had significantly lower fat than that of control ice cream. The low fat ice cream and normal average ice cream complied with the PFA standards.

<table>
<thead>
<tr>
<th>Type of ice cream</th>
<th>Constituents (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fat</td>
</tr>
<tr>
<td>C</td>
<td>10.18</td>
</tr>
<tr>
<td>T1</td>
<td>2.07</td>
</tr>
<tr>
<td>T2</td>
<td>2.07</td>
</tr>
</tbody>
</table>

Statistical analysis

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>0.055</th>
<th>0.046</th>
<th>0.013</th>
<th>0.166</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD(0.05)</td>
<td>0.146</td>
<td>0.166</td>
<td>0.138</td>
<td>NS</td>
<td>0.499</td>
</tr>
</tbody>
</table>
C: Regular fat ice cream

The average value of protein in control ice cream was 5.15 while for low fat creamplus containing (T1) ice cream it was 5.57 and for butterbuds (T2) ice cream the value was 5.61 per cent. The low fat ice creams had significantly higher protein content compared to that of control. The high values of protein is due to high amount of MSNF plus the protein contributed by 2.0 per cent cocoa powder as discussed in section 4.1.1.

The average values of reducing and non-reducing sugar for all the ice creams are shown in Table 4.7 It is seen from table that the reducing sugar content of low fat ice cream are significantly higher than that of control ice cream. The low fat ice cream contained higher amount of MSNF which was responsible for the high values of reducing sugar (Table 4.6). Non-reducing sugar content of low fat ice cream was not significantly different from that of control ice cream. Low fat ice cream had significantly low total solids content. The total solids content of low fat ice cream and average fat ice cream are as per PFA standard.

### 4.2.2.2 Physical properties

Table 4.8 shows the average values of physical parameters viz. acidity, viscosity, overrun and melting resistance of controlled
normal fat chocolate ice cream and low fat chocolate ice creams prepared with use of sago with addition of two distinct flavours, butter buds and cream buds.

Table 4.8: PHYSICAL PROPERTIES OF CHOCOLATE ICE CREAM

<table>
<thead>
<tr>
<th>Type of ice cream</th>
<th>Acidity (% LA)</th>
<th>Viscosity (mPas)</th>
<th>Overrun</th>
<th>Melting resistance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.208</td>
<td>69.67</td>
<td>55.21</td>
<td>51.6</td>
</tr>
<tr>
<td>T1</td>
<td>0.215</td>
<td>84.5</td>
<td>52.63</td>
<td>44.2</td>
</tr>
<tr>
<td>T2</td>
<td>0.214</td>
<td>86</td>
<td>52.62</td>
<td>44.75</td>
</tr>
</tbody>
</table>

Statistical analysis

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>CD(0.05)</th>
<th>C.V.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEM</td>
<td>0.003</td>
<td>0.008</td>
<td>2.89</td>
</tr>
<tr>
<td>CD(0.05)</td>
<td>1.016</td>
<td>3.061</td>
<td>3.11</td>
</tr>
<tr>
<td>C.V.%</td>
<td>0.925</td>
<td>NS</td>
<td>4.24</td>
</tr>
</tbody>
</table>

* g of ice cream melted at 37.5°C for 40 min.

T1: Creamplus and sago containing low fat experimental ice cream
T2: Butterbuds and sago containing low fat experimental ice cream
C: Regular fat ice cream

The average value of acidity for control ice cream mix was 0.208 per cent LA, which was significantly lower than that of experimental mixes T1 and T2, the acidity values were 0.215 and 0.214 per cent LA respectively. The higher acidity of experimental mixes could be ascribed to higher MSNF content in such mixes.

The control mix had the least viscosity after ageing (69.67 mPas). The viscosity of experimental mixes T1 and T2 was higher which were 84.5 and 86.0 mPas respectively. Such an increase in viscosity was found to be significant when compared the two experimental mixes. The higher viscosity of low fat ice cream mixes is discussed in detail at section 4.2.1.2.
Table 4.8 depicts the average value of overrun of ice creams. The table shows that the overrun of control ice cream was slightly higher than that of low fat sago based ice creams. The overrun values of all ice creams were statistically non-significant. It is observed that the overrun of control and low fat experimental ice creams were at par with each other.

It is evident from the tabulated results that the control samples of ice cream had the least melting resistance as reflected from the maximum average value of ice cream melted under the condition of the test. The melting resistance of sago based low fat ice cream samples exhibited improved melting resistance when compared to control ice cream. Both the experimental ice creams made using sago had significantly slower meltdown as compared to control. However, both the experimental samples had nearly similar melting resistance.

4.2.2.3 Sensory quality:

Table 4.9 shows the average values of sensory parameters viz. flavour, body and texture, melting quality, colour and appearance, and total sensory score of control and sago based low fat chocolate ice creams containing either butterbuds or creamplus as flavour adjunct.

It is evident from the tabulated values that both the fresh experimental ice creams had flavour score similar to the one scored
by control ice cream. The experimental sago based low fat ice cream using butterbuds had slightly higher score over control and creamplus based low fat chocolate ice cream. Prindiville et al. (1999) reported that milk fat at 9.0 and 6.0 per cent level produced less intense cocoa flavour than at concentration of 4 and 0.5 per cent. They further reported that in low fat chocolate ice cream the cocoa flavour was perceived better, however, it had low creaminess. In current study sample T2 not only had desired chocolate flavour, but also it had creaminess too probably contributed by butterbuds.

Table 4.9: SENSORY QUALITY OF CHOCOLATE ICE CREAM

<table>
<thead>
<tr>
<th>Type of ice cream</th>
<th>Sensory scores for</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flavour</td>
</tr>
<tr>
<td>C</td>
<td>37.09</td>
</tr>
<tr>
<td>T1</td>
<td>36.24</td>
</tr>
<tr>
<td>T2</td>
<td>37.3</td>
</tr>
</tbody>
</table>

Statistical analysis

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>CD(0.05)</th>
<th>C.V.%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.379</td>
<td>NS</td>
<td>2.52</td>
</tr>
<tr>
<td></td>
<td>0.269</td>
<td>NS</td>
<td>2.46</td>
</tr>
<tr>
<td></td>
<td>0.089</td>
<td>NS</td>
<td>5.28</td>
</tr>
<tr>
<td></td>
<td>0.109</td>
<td>NS</td>
<td>6.32</td>
</tr>
<tr>
<td></td>
<td>0.33</td>
<td>NS</td>
<td>6.32</td>
</tr>
<tr>
<td></td>
<td>0.272</td>
<td>NS</td>
<td>6.32</td>
</tr>
<tr>
<td></td>
<td>0.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.77</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

T1: Creamplus and sago containing low fat experimental ice cream
T2: Butterbuds and sago containing low fat experimental ice cream
C: Regular fat ice cream

In terms of body and texture there was non significant difference between sago containing experimental samples and control ice creams. Sago was found to enhance the viscosity of experimental ice cream mix significantly, as has been delineated and discussed earlier section 4.2.1.2. and 4.2.1.3., which might have been responsible for the slight improvement in the body of ice cream.
Prindiville *et al.* (1999) reported greater chalkiness, fat melting rate and lower smoothness in low fat chocolate ice cream.

The sago based low fat chocolate ice creams exhibited melting characteristics similar to that of normal (10 per cent) fat control ice cream (Figure 4.3). The melting quality of control and experimental low fat ice creams were statistically at par. The marginally superior melting quality scored of experimental samples over control ice cream. The good melting quality could be ascribed to the significantly superior viscosity obtained through use of gelatinized sago, complemented by solids from cocoa powder too.

The colour and appearance score of low fat experimental chocolate ice creams were significantly higher than that of control ice cream. The average scores were 3.94, 4.33 and 4.41 for control, experimental ice cream T1 and T2 respectively. The higher score assigned to low fat ice creams was due to their clear intense chocolate brown colour (Figure 4.4) as compared to dull brown colour in control ice cream. The uneven dull colour of control ice cream might be due to presence of higher fat globules in the ice cream matrix. No report is there to scientifically explain the better reflectance of light from chocolate ice cream having low fat content.

The average of total sensory score of low fat ice creams and control ice cream are tabulated in Table 4.9. It is seen from the table that the total sensory score of low fat chocolate ice cream containing butterbuds was significantly higher than that of control or low fat
chocolate ice cream containing creamplus. The total sensory score of ice creams revealed that all the ice creams had high acceptability.

It can be concluded that sago served as a functional ingredient in low fat chocolate ice cream using butterbuds as flavour enhancer. Such ice cream was comparable to normal fat ice cream in terms of body and texture, melting characteristics, and colour and appearance.

4.2.3 LOW FAT MANGO ICE CREAM CONTAINING SAGO:

The next variety tried out was fruit ice cream viz. Mango flavouring. Alphonso mango pulp was used for flavouring. Mango pulp imparts total solids to ice cream. Slight modification in the tentative formulation was required which was decided based on preliminary trials. The level of mango pulp required to give optimum flavour in ice cream was 20 per cent by weight of the mix. The level of sago and stabilizer were 2.5 and 0.025 per cent respectively, the same was kept in chocolate ice cream too. The sago based low fat mango ice cream was prepared using either creamplus or butterbuds to improve the richness of low fat ice cream. These two low fat mango ice creams were compared against normal fat (10 per cent fat) mango ice cream. Totally six replications were undertaken. The results of experiment was statistically analyzed and discussed under three main categories: chemical composition, physical properties and sensory evaluation.
Table 4.10: Formulation for low and full fat mango ice cream

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Constituents</th>
<th>Mango ice cream</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low fat</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Regular fat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Milk Fat</td>
<td>2.4</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>MSNF</td>
<td>14.0</td>
<td>12.5</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Sucrose</td>
<td>13.0</td>
<td>13.0</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Sodium Alginate</td>
<td>0.025</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>GMS</td>
<td>0.20</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Sago</td>
<td>2.5</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Alphonso mango pulp</td>
<td>20.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Creamplus/Butterbuds</td>
<td>0.2/0.05</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total solids</td>
<td>37.33/37.18</td>
<td>40.85</td>
<td></td>
</tr>
</tbody>
</table>

4.2.3.1 Chemical composition:

Table 4.11 shows the average values of compositional parameters viz. fat, protein, reducing and non-reducing sugars, and total solids of control and low fat mango ice creams.

The average values of fat for control ice cream was 10.25 and for low fat ice cream it was 2.38 per cent as shown in Table 4.11. The low fat ice cream had significantly lower fat than that of control ice cream. The low fat ice cream and control ice cream conformed to the PFA standards.
The average value of protein in control ice cream was 4.74 while for low fat T1 and T2 ice creams it was 5.12 and 5.21 respectively. The low fat ice creams had significantly higher protein compared with that of control. The higher value of protein was due to high MSNF (14.0 vs. 12.5 in control) as discussed in section 4.1.1.

**Table 4.11: CHEMICAL COMPOSITION OF MANGO ICE CREAM**

<table>
<thead>
<tr>
<th>Type of ice cream</th>
<th>Constituents (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fat</td>
</tr>
<tr>
<td>C</td>
<td>10.25</td>
</tr>
<tr>
<td>T1</td>
<td>2.38</td>
</tr>
<tr>
<td>T2</td>
<td>2.38</td>
</tr>
</tbody>
</table>

**Statistical analysis**

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>CD(0.05)</th>
<th>C.V. %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.06</td>
<td>0.18</td>
<td>2.95</td>
</tr>
<tr>
<td></td>
<td>0.042</td>
<td>0.12</td>
<td>2.01</td>
</tr>
<tr>
<td></td>
<td>0.044</td>
<td>0.13</td>
<td>1.39</td>
</tr>
<tr>
<td></td>
<td>0.016</td>
<td>NS</td>
<td>0.31</td>
</tr>
<tr>
<td></td>
<td>0.121</td>
<td></td>
<td>0.76</td>
</tr>
</tbody>
</table>

T1: Creamplus and sago containing low fat experimental ice cream

T2: Butterbuds and sago containing low fat experimental ice cream

C: Regular fat ice cream

The average values of reducing sugar and non-reducing sugar for all the ice creams are shown in Table 4.11. It is seen from table that the reducing sugars of low fat ice cream were significantly higher
than that of control ice cream. The low fat ice creams had higher amount of MSNF and thus lactose content. Moreover the reducing sugar from mango pulp contributed to the higher reducing sugar.

Non-reducing sugar content of low fat ice cream did not differ significantly from that of control ice cream.

Low fat ice cream had significantly low total solids content than control ice cream. Total solid content of low fat ice cream and average fat (10 per cent fat) ice cream conformed to the PFA standards.

4.2.3.2 Physical properties

Table 4.12 shows the average values of physical parameters viz. acidity, viscosity, overrun and melting resistance of control and sago based low fat mango ice creams.

<table>
<thead>
<tr>
<th>Type of ice cream</th>
<th>Acidity (% LA)</th>
<th>Overrun</th>
<th>Melting resistance*</th>
<th>Viscosity with pulp (mPas)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without pulp</td>
<td>with Pulp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0.208</td>
<td>0.507</td>
<td>52.47</td>
<td>50.09</td>
</tr>
<tr>
<td>T1</td>
<td>0.214</td>
<td>0.523</td>
<td>49.38</td>
<td>42.98</td>
</tr>
<tr>
<td>T2</td>
<td>0.214</td>
<td>0.523</td>
<td>48.41</td>
<td>44.18</td>
</tr>
</tbody>
</table>

Statistical analysis

<table>
<thead>
<tr>
<th></th>
<th>SEM</th>
<th>CD(0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.002</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>0.006</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>0.765</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>0.559</td>
<td>1.68</td>
</tr>
<tr>
<td></td>
<td>0.735</td>
<td>2.22</td>
</tr>
</tbody>
</table>
C.V.% | 2.81 | 2.99 | 3.74 | 2.99 | 2.24

* g of ice cream melted at 37.5°C for 40 min.

T1: Creamplus and sago containing low fat experimental ice cream

T2: Butterbuds and sago containing low fat experimental ice cream

C: Regular fat ice cream

The average value of acidity for control ice cream mix was 0.208 per cent LA, which was significantly lower than that of experimental mixes T1 and T2, the acidity was 0.214 and 0.214 per cent LA respectively. The higher acidity of experimental mixes could be ascribed to higher MSNF content; the rate of mango pulp addition being same in both cases.

The control mix had the least viscosity after ageing (70.67 mPas). The viscosity of experimental mixes T1 and T2 was higher which was 85.0 mPas and 85.67 mPas respectively. Such an increase in viscosity was found to be significant for experimental mixes. The higher viscosity in the low fat ice cream mixes is discussed in detail at section 4.2.1.2.

Table 4.12 depicts the average value of overrun of ice creams. The table shows that the overrun of control ice cream was slightly higher than that of low fat mango ice creams. The overrun values of all ice creams were statistically non significant. This slightly high overrun in control ice cream discussed in section 4.2.1.2.
It is evident from the tabulated results that the control ice cream had minimum melting resistance as evident from the maximum values of ice cream melted under the test conditions. The melting resistance of sago containing low fat ice cream samples was significantly greater compared to control ice cream. Both the experimental samples made using sago had similar melting resistance. This is discussed in section 4.2.1.2.

The average value of acidity of control mix after addition of pulp was 0.507 per cent LA which was slightly lower than average values of both low fat mixes which was 0.523 per cent LA. The value of acidity after addition of pulp is not reported.

### 4.2.3.3 Sensory quality:

Table 4.13 shows the average values of sensory parameters viz. flavour, body and texture, melting quality, colour and appearance, and total sensory score of control and low fat mango ice creams.

It is evident from the tabulated values that fresh sago based experimental ice creams made using creamplus or butterbuds were statistically similar to control ice cream in terms of flavour score. The experimental ice cream prepared with creamplus was slightly superior to control and low fat ice cream with butterbuds. The use of mango pulp as flavourings makes the ice cream very delicious.

In terms of body and texture there was non-significant difference between experimental samples and control. Inclusion of sago was responsible for improving the body of low fat mango ice
cream to make them as good as control with respect to body and texture score.

The sago based low fat mango ice creams had melting characteristics as good as that of normal (10 per cent) fat control ice cream (Figure 4.5). The melting score of control ice cream and experimental low fat ice creams were statistically at par. However, the average melting score of experimental sample were slightly higher than that of control ice cream. The good melting quality of experimental ice cream has been discussed in section 4.2.1.3.

Table 4.13: SENSORY QUALITY OF MANGO ICE CREAM

<table>
<thead>
<tr>
<th>Type of ice cream</th>
<th>Sensory score for</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flavour</td>
<td>Body &amp; texture</td>
<td>Melting quality</td>
<td>Colour and appearance</td>
<td>Total sensory score</td>
</tr>
<tr>
<td>C</td>
<td>37.03</td>
<td>26.84</td>
<td>4.05</td>
<td>4.00</td>
<td>86.91</td>
</tr>
<tr>
<td>T1</td>
<td>37.15</td>
<td>27.04</td>
<td>4.20</td>
<td>4.24</td>
<td>87.62</td>
</tr>
<tr>
<td>T2</td>
<td>35.36</td>
<td>26.94</td>
<td>4.16</td>
<td>4.24</td>
<td>85.69</td>
</tr>
</tbody>
</table>

Statistical analysis

<table>
<thead>
<tr>
<th>SEM</th>
<th>0.597</th>
<th>0.289</th>
<th>0.087</th>
<th>0.097</th>
<th>0.616</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD(0.05)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>
The colour and appearance score of low fat experimental mango ice creams were slightly higher than that of control ice cream. The average scores were 4.05, 4.20 and 4.16 for control, experimental ice cream T1 with creamplus and experimental ice cream T2 with butterbuds respectively. All the score for colour and appearance of mango ice creams were statistically at par with each other. The higher colour score of low fat ice creams were as a consequences of clear, intense yellowish orange colour compared to control ice cream (Figure 4.6). The dull colour of control ice cream might be due to higher milk fat content. There is no report on reasoning for better reflectance of mango colour in low fat ice creams. The sago might have interacted with pigment in mango to make them intense.

The average of total sensory score of low fat ice creams and control ice cream are tabulated in Table 4.13. It is seen from the table that the total sensory score of low fat mango ice creams containing creamplus was slightly higher than that of control ice cream as well as that of low fat ice cream containing butterbuds; the corresponding scores were 87.62, 86.91 and 85.69 respectively. The values of total sensory score for all the ice creams were statistically at par with each
other. The total sensory score of all the ice creams showed that all the ice creams had highly acceptable sensory quality.

4.3 HEAT SHOCK RESISTANCE:

Assessing the effect of heat shock on sensory properties of the formulated sago based low fat ice cream is important for forecasting its suitability or otherwise in actual market conditions.

The sensory quality of heat shocked low fat vanilla ice cream was adjudged by a panel of seven judges. Heat shock occurs primarily during distribution and storage of ice cream. Heat shock is considered responsible for the growth of ice crystals in ice cream making them coarse, icy texture. Several such heat shock cycles may alter the properties of milk proteins, stabilizer and other solids present in ice cream matrix, viz. decreased water binding capacity, decrease in stability of air cells, etc. and thereby adversely affect the body and texture and even flavour characteristics of ice cream. Hence, seven heat shock cycles (keeping the ice creams in a temperature controlled area at 22 °C for 1.5 h for the first day and 0.5 h everyday for 6 subsequent days followed by keeping constantly at <-18 °C; Section 3.9) were simulated and the overall sensory quality of the heat shocked low fat ice cream adjudged.

The hardened low fat ice cream meted out with heat shock treatment (section 3.9) was compared with hardened control ice cream meted out with same treatment. Heat shock treatment was applied during one replication of vanilla flavoured ice cream and the
sensory attributes evaluated by judges are tabulated in Table 4.14. The results obtained are discussed hereunder.

As seen from the Table 4.14, the average flavour score of all the samples did not differ much. Average flavour score assigned were 37.16, 35.18 and 37.06 for heat shocked low fat ice cream with creamplus, low fat ice cream with butterbuds and control respectively. The average flavour score on 0\textsuperscript{th} day assigned were 37.41, 35.20 and 37.36 for low fat ice cream with creamplus, low fat ice cream with butterbuds and control respectively. However, the difference in the average flavour score of heat shocked and fresh ice creams had very small difference observed from table 4.14.

Table 4.14 shows the influence of heat shock on the body and texture scores of low fat ice cream and control ice cream. The average body and texture score on 0\textsuperscript{th} day assigned were 25.24, 27.11 and 27.25 for low fat ice cream with creamplus, low fat ice cream with butterbuds and control respectively. Average body and texture score assigned were 25.17, 27.01 and 26.97 for heat shocked low fat ice cream with creamplus, low fat ice cream with butterbuds and control respectively. The score for body and texture of heat shocked ice creams were slightly less than fresh ice cream.

Table 4.14: SENSORY CHARACTERISTICS OF HEAT SHOCKED VANILLA ICE CREAMS

<table>
<thead>
<tr>
<th>Type of ice</th>
<th>Average sensory scores</th>
</tr>
</thead>
</table>

Results and discussion
<table>
<thead>
<tr>
<th>Sensory attributes</th>
<th>cream</th>
<th>On 0\textsuperscript{th} day</th>
<th>On 7\textsuperscript{th} day (Heat shocked)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flavour (max. score 45)</td>
<td>T1</td>
<td>37.41</td>
<td>37.16</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>35.20</td>
<td>35.18</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>37.36</td>
<td>37.06</td>
</tr>
<tr>
<td>Body &amp; texture (max. score 30)</td>
<td>T1</td>
<td>25.24</td>
<td>25.17</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>27.11</td>
<td>27.01</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>27.25</td>
<td>26.97</td>
</tr>
<tr>
<td>Melting quality (max. score 5)</td>
<td>T1</td>
<td>4.11</td>
<td>4.06</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>4.12</td>
<td>4.09</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>3.89</td>
<td>3.79</td>
</tr>
<tr>
<td>Colour and appearance (max. score 5)</td>
<td>T1</td>
<td>4.40</td>
<td>4.40</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>4.33</td>
<td>4.33</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4.00</td>
<td>4.00</td>
</tr>
<tr>
<td>Total sensory score (max. score 100)*</td>
<td>T1</td>
<td>86.16</td>
<td>85.79</td>
</tr>
<tr>
<td></td>
<td>T2</td>
<td>85.76</td>
<td>85.61</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>87.50</td>
<td>86.79</td>
</tr>
</tbody>
</table>

* Full marks are considered i.e. 15 for bacterial count

T1: Creamplus and sago containing low fat experimental ice cream

T2: Butterbuds and sago containing low fat experimental ice cream

C: Regular fat ice cream

Table 4.14 shows the influence of heat shock on the melting quality of low fat ice cream and control ice cream. The average melting quality score on 0\textsuperscript{th} day assigned were 4.11, 4.12 and 3.89 for low fat ice cream with creamplus, low fat ice cream with butterbuds and control respectively. Average body and texture score assigned were 4.06, 4.09 and 3.79 for heat shocked low fat ice cream with creamplus, low fat ice cream with butterbuds and control.
respectively. The score for melting quality of heat shocked ice creams were slightly less than fresh ice cream.

Table 4.14 shows the influence of heat shock on the colour and appearance score of experimental and control ice creams. The average colour and appearance score on 0\textsuperscript{th} day assigned were 4.40, 4.33 and 4.0 for low fat ice cream with creamplus, low fat ice cream with butterbuds and control respectively. The average colour and appearance score for heat shocked ice creams had similar values as for fresh ice cream.

The total scores which indicate the overall acceptability of the product are presented in Table 4.14. The average total score on 0\textsuperscript{th} day assigned were 86.16, 85.76 and 87.50 for low fat ice cream with creamplus, low fat ice cream with butterbuds and control respectively. Average total score assigned were 85.79, 85.61 and 86.79 for heat shocked low fat ice cream with creamplus, low fat ice cream with butterbuds and control respectively. The tabulated values reveal that the average total scores less very slightly in magnitude after heat shock treatment.

Thus, it can be concluded from this part of the study that heat shock treatment had no adverse effect on the quality of low fat vanilla ice creams formulated by sago as functional ingredient. This implies that use of sago along with marginal amount of sodium alginate could afford heat shock protection to product as does commercial stabilizers in control full fat ice cream.
4.4 COMMERCIAL ICE CREAM FREEZING TRIAL

The commercial success of any new ingredient depends on the consumer response. Consumer response studies play a key role in launching newly developed product in the market. Therefore, the low fat ice creams frozen in a direct expansion type 'batch-freezer' (capacity 20 lit.) manufactured using the recipe formulated in the present study and was also evaluated through a consumer survey conducted by selecting randomly 85 consumers representing different segments of the society.

The composition for the both the low fat ice cream and control were kept same as studied earlier. For each flavour of low fat ice cream (vanilla, chocolate, mango) the one obtaining highest (section 4.2.1.3; 4.2.2.3 and 4.2.3.3), out of butterbuds and creamplus was selected for final commercial trial. So for vanilla and mango flavoured low fat ice cream the ‘creamplus’ was employed for commercial trial, while for chocolate ice cream the ‘butterbuds’ was selected. The procedure of preparation of mix employed was the same in experimental and control ice creams.

For consumer acceptance trial in the present project, the product was manufactured as per the procedure used earlier and packed in 100 ml HIPS cups. The frozen dessert cups were distributed to 85 probable consumers and their comments recorded in a specifically developed proforma (Appendix III). The consumers
were asked to indicate whether they like the product or not, and if yes, to what level i.e. “Excellent”, “Very Good” or “Good”.

It can be seen from the Table 4.2 that the fat content of the low fat ice cream prepared with addition of sago was lower almost by 76 per cent than that of average ice cream (10.00 per cent). However, the total milk fat in low fat ice cream is only 2.4 per cent. The low fat ice cream prepared in direct expansion type freezer gives overrun in between 90 to 105.

According to PFA standards in India, the formulated low fat ice cream meets the standards for low fat ice cream with respect to the total solids (min 26.0 per cent required), total fat (max. 2.5 per cent required) and total protein (min. 2.5 per cent required).

All the six samples are given to 85 consumers and evaluated for sensory characteristics. For the different sensory attributes viz. flavour, body and texture, melting quality, colour and appearance and total sensory score the consumers find no difference in our low fat ice cream prepared with use of sago and average fat control ice cream. Even few of the customer liked more our product in terms of colour and appearance, melting quality and richness. The figures 4.7, 4.8 and 4.9 show the photo of industrial trial for vanilla flavour, chocolate flavour and mango flavour respectively.

None of the consumers disliked the product. Out of 85 consumers who judged the product, 55.0 per cent rated it as excellent, 33.7 per cent rated it as very good and 11.3 per cent rated it as good. This indicates that the product has a good potential for

*Results and discussion*
marketing. The consumers, in general commented that such a product if available in the market would enormously benefit those who are health conscious, calorie conscious and those are poor.

4.5 COMPARISON OF ENERGY VALUE OF THE DIETETIC LOW FAT ICE CREAM WITH AN AVERAGE ICE CREAM

This section of discussion would deal with the calculation of the calorific values of low fat sago contained vanilla ice cream and average (10 per cent fat) control vanilla ice cream.

The property whereby a food produces heat and energy within the body may be expressed in terms of energy value. Ice cream is an excellent source of food energy. The fact that the constituents of ice cream are almost completely assimilated makes ice cream an especially desirable food for growing children and for persons who need to put on weight. For the same reason, its controlled use finds a place in the diet of persons who need to reduce weight (Marshall et al. 2003).

The energy value was calculated by taking the energy value for fat, protein and carbohydrates as follows: fat, 8.79; protein 4.27 and carbohydrates, 3.87cal/g. Based on the data, the energy value of an average ice cream mix is 185.62 cal/100g. The energy value of the

Results and discussion
dietetic low fat ice cream was 130.04 cal/100g (Table 4.15). It represents a 30 per cent reduction. As per U.S. food labeling regulations implemented in 1994 reduced or fewer calories food means 25% or less calories/serve than regular product (Anon, 2007b). Therefore, the developed low fat ice cream can be classified as a reduced calorie low fat ice cream as per the US regulations. However, at present no such description is reported under PFA regulations in India. Further reduction of in calories if required, it can be achieved by minor adjustment in the formulations of low fat ice cream such as slight reduction in MSNF and fat content coupled with suitable changes in use of stabilizer.

Table 4.15: Calculated calorific value of the vanilla flavoured dietetic low fat vs. an average ice cream mix (per 100 g mix).

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Ingredient</th>
<th>Dietetic low fat (per cent)</th>
<th>Low fat ice cream energy (Kcal)</th>
<th>Regular percent (%)</th>
<th>Ice cream energy (Kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fat</td>
<td>2.38</td>
<td>20.9</td>
<td>10.23</td>
<td>90.0</td>
</tr>
<tr>
<td>2.</td>
<td>MSNF*</td>
<td>13.09</td>
<td>48.0</td>
<td>11.77</td>
<td>43.1</td>
</tr>
<tr>
<td>4.</td>
<td>Sugar</td>
<td>12.87</td>
<td>49.8</td>
<td>12.91</td>
<td>50.0</td>
</tr>
<tr>
<td>5.</td>
<td>Sodium alginate</td>
<td>0.05</td>
<td>0.19</td>
<td>0.20</td>
<td>0.77</td>
</tr>
<tr>
<td>6.</td>
<td>GMS</td>
<td>0.20</td>
<td>1.75</td>
<td>0.20</td>
<td>1.75</td>
</tr>
<tr>
<td>7.</td>
<td>Sago**</td>
<td>2.43</td>
<td>9.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total calories</td>
<td></td>
<td>130.04</td>
<td></td>
<td>185.62</td>
</tr>
</tbody>
</table>
Percent reduction in calories | 29.95 = ~30

*MSNF contain approx. 36 per cent protein and 55 per cent lactose

**Sago contained 12 per cent moisture and 7 per cent resistant starch which do not impart energy.

4.6 COMPARISON OF COST FOR LOW FAT WITH FULL FAT ICE CREAM

This section deals with the calculation of cost effectiveness of the low fat sago contained vanilla ice cream compared to an average vanilla ice cream. The data are presented in Table 4.16

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Rate (Rs/kg)</th>
<th>Low fat ice cream Quantity (kg)</th>
<th>Rs.</th>
<th>Normal ice cream Quantity (kg)</th>
<th>Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk (6.0% fat, 9.0 % MSNF)</td>
<td>23</td>
<td>40.00</td>
<td>920.00</td>
<td>70.43</td>
<td>1619.90</td>
</tr>
<tr>
<td>Skim milk (0.1% fat, 8.99 MSNF)</td>
<td>12</td>
<td>36.16</td>
<td>433.92</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
The low fat ice cream developed in the current project is low in milk fat/ fat content, higher protein content, and good healthy carbohydrate content. The cost of this low fat ice cream is carried out in this section. The cost of the low fat ice cream is compared with an average ice cream having the composition as given in earlier sections. The cost of any product mainly depends on the cost of raw ingredients used in preparing the product. An endeavour is made to assess the cost of the product. The current cost of raw materials had been utilized to serve as a basis of costing. The total cost of raw material of one kg mix of both types is given in Table 4.16. Since the method of manufacture is the same the processing costs were not compared.

As can be seen from Table 4.16 there is 24.24 per cent reduction in the cost of raw material of the low fat ice cream. Pinto
(2006) reported a cost reduction of 17.8 per cent for formulated dietetic frozen dessert. Abdou et al. (1995) reported that replacing sugar with polydextrose and aspartame raised the production cost by 242.99 per cent. Verma (2002) reported a 14.5 per cent increase in cost of raw material in a sugar free ice cream using maltodextrin, sorbitol and aspartame.
SUMMARY AND CONCLUSIONS

In recent years low fat, low calorie, reduced calorie, diabetic and dietetic foods have become increasingly popular in all segments of the society. The successful development of good quality dietetic food would depend to a large extent on the imitation and simulation of organoleptic properties of the equivalent standard products.

The development of low fat ice cream with matching quality of the full fat ice cream depended on replacing the fat with alternative ingredients (fat replacers) which can impart physical and rheological properties as fat in low fat ice cream.

Starch is a major polysaccharide of higher plants. Starch is added as a functional ingredient to many products including a variety of low-fat products. Sago is a processed edible natural starch marketed in the form of small globules or pearls. In India, the sago of commerce is manufactured mainly from tapioca starch. It is known as tapioca pearl or sabudana in Indian market. In present study suitability of sago was evaluated in dietetic low fat ice cream.

The basic three varieties of ice cream are plain ice cream, chocolate ice cream and fruit & nut ice cream. In this study one flavour from each variety selected and that was Vanilla, Chocolate and Mango. Various results obtained during this investigation as given in chapter 4 are presented here under in summarized form.
5.1 FORMULATION OF ICE CREAM:

The tentative formulation for ice cream was selected based on primary trials.

5.1.1 FORMULATION OF LOW FAT ICE CREAM:

Primary trials were done to select the level of sago, form of sago, MSNF, Sugar, Medium for Sago gelatinization, quantity of medium of gelatinization, stabilizer quantity, rate of different flavouring (vanilla, creamplus, butterbuds, cocoa powder and mango pulp) and colouring.

Looking to the mandatory standards (PFA) of maximum 2.5 per cent fat, fat level fixed at 2.4 per cent for low fat ice cream. The MSNF content tried out at levels 13.5, 14.0 and 14.5 per cent (w/w) respectively. Low fat ice cream with 14 per cent MSNF gave good body and texture without having pronounced powdery taste. Hence, a level of 2.4 per cent fat and 14 per cent MSNF was chosen in the tentative formulation.

During preliminary screening the sweetness of sucrose was found to increase as fat contents was decreased. Therefore to select the level of sucrose in the tentative formulation in the preliminary screening sucrose was used at the rate of 12.5, 13 and 13.5 per cent (w/w) in the formulation of the low fat ice cream. For obtaining a low
fat ice cream with optimum sweetness it was found to add sucrose at the rate of 13 per cent. Hence, a level of 13 per cent sucrose was chosen in the tentative formulation.

In the preliminary trials, water and skimmed milk were tried as a medium for gelatinization of sago. Use of skimmed milk as gelatinization medium was found more suitable. Therefore it was finely selected for the further work.

For quantity of medium different trials of gelatinization had taken. For 300 g sago, skim milk were taken 600 g, 800g, 1000g and 1200g. The gel prepared with 1000 g of skimmed milk shows good body and texture and gelatinized mass satisfactorily got incorporated in ice cream mix. Therefore, level of 1000g skimmed milk per 300g sago was selected for gelatinization.

The maximum level of starch permitted in ice cream is 30 g per Kg ice cream mix as per PFA Rule (2006). Three levels of sago selected for addition in low fat ice cream i.e. 1, 2 and 3 per cent. The maximum level of sago that was 3 per cent gave slight weak and watery body. However, it was not possible to increase the addition beyond 3 per cent due to legal constraint; therefore, a level of sago finely selected was 3 per cent. Since addition of sago @ 3 per cent was giving slightly weak and watery body, addition of stabilizer was necessitated. Widely used sodium alginate was used as a stabilizer in present study. Based on preliminary trials it was decided to use sodium alginate 0.05 per cent.
Based on preliminary trials it was decided to use GMS at the rate of 0.20 per cent in the formulation. Higher than 0.20 per cent use of GMS showed no significant improvement in the quality of the product whereas at levels less than 0.20 per cent level gave a product which was slightly coarse in texture. Hence, a level of 0.20 per cent GMS was chosen in the tentative formulation. From the experimentation carried out, the tentative formulation of the low fat ice cream was decided as milk fat: 2.4, MSNF: 14.0, Sucrose: 13.0, Sodium alginate: 0.05, GMS: 0.2 and Sago 3.0 per cent.

To give a flavour of fat to such low fat ice cream butterbuds and creamplus available in the market was used. Different levels of such natural concentrate was tried and selected final level, which was 0.2 per cent for cream flavour and 0.05 per cent for butterbuds.

5.1.2 FORMULATION OF NORMAL FAT ICE CREAM:

The formulation of control vanilla ice cream was; Fat: 10.0 per cent, MSNF: 12.5 per cent, Sucrose: 13 per cent; Sodium alginate: 0.2 per cent; GMS: 0.2 per cent and vanilla flavour 0.8 ml/kg of ice cream mix.

5.2 COMPARATIVE APPRAISAL OF LOW FAT ICE CREAM WITH GOOD AVERAGE ICE CREAM:

Initially home made ice cream was prepared using the various flavour combinations in sago contained low fat ice cream and chemical composition, physical properties and sensory attributes of
experimental ice cream were evaluated, keeping normal fat (10 per cent) ice cream as control.

The physico-chemical and sensory characteristics of the low fat sago contained ice cream was made against a good average ice cream. Three different flavours viz. vanilla, chocolate and mango taken for assessing the physico-chemical and sensory characteristics of the low fat ice cream against a good average ice cream

5.2.1 LOW FAT VANILLA ICE CREAM USING SAGO:

After deciding the tentative formulation of low fat ice cream using sago, it was first tried with vanilla flavourings with decided level of creamplus and butterbuds i.e. 0.2 and 0.05 per cent respectively. These two low fat ice creams were compared with normal fat vanilla ice cream. The results were discussed under three main categories: chemical composition, physical properties and sensory evaluation.

5.2.1.1 Chemical composition:

Compositional parameters viz. fat, protein, reducing and non-reducing sugars, and total solids of controlled normal fat vanilla ice cream and low fat vanilla ice creams prepared with use of sago with addition of two distinct flavours, butterbuds and creamplus in addition to require vanilla flavour were studied.

The average values for the fat of controlled ice cream were 10.23 and for low fat ice cream were 2.38. The low fat ice cream contains
significantly low fat than that of control ice cream. The low fat and normal average fat ice creams were within the PFA standards.

The low fat ice cream significantly contains high protein while compared with control. The high protein contain was due to high MSNF added in low fat ice cream. The values of protein content in all the ice creams were well above the minimum prescribed standard for ice cream under PFA Act.

The reducing sugars of low fat ice creams were significantly higher than that of control ice cream. The values were 7.16, 7.95 and 7.96 respectively for control, low fat ice cream with creamplus and low fat ice cream for butterbuds. Non-reducing sugar content of low fat ice cream was not significantly differing from that of control ice cream. The non-reducing sugars mainly represent the added sucrose in ice cream. Low fat ice cream had significantly low total solids content. Total solid content of low fat ice cream and average fat ice cream were full filling the requirement of mandatory standards.

The compositional attributes were well above the minimum values specified for normal ice cream and low fat ice cream as recommended by PFA (1955).

5.2.1.2 Physical properties:

Physical parameters studied were acidity, viscosity, overrun and melting resistance. The average value of acidity for control ice cream mix was 0.212 per cent LA, which was significantly low than experimental mixes T1 and T2 which had acidity value 0.222 and
0.221 respectively. The values of acidity observed in present study were within the range of acidity reported.

The control mix had the least viscosity after ageing (71.33 mPas). The viscosity of experimental mixes T1 and T2 was higher which were 86.33 mPas and 85.17 mPas respectively. Such increase in viscosity was found significant at each experimental mixes. The viscosity values of all the ice cream mixes were within this range. The higher viscosity value was due to added sago as an ingredient, which was helpful in producing good physical and sensory quality of low fat ice cream.

The average value of overrun of ice cream was 56.05, 52.64 and 53.1. The overrun of control ice cream was slight higher than the low fat sago contained ice creams. The difference in overrun values of all ice creams were non significant.

The control samples of ice cream had a minimum melting resistance as reflected from the maximum average values of ice cream melted. The melting resistance of low fat ice cream samples where sago was used showed improved melting resistance over the control ice cream. Both the experimental samples had nearly similar values for melting resistance.

5.2.1.3 Sensory quality:

Sensory parameters studied were flavour, body and texture, melting quality, colour and appearance, and overall acceptability. The
sensory quality of the ice cream samples were adjudged by a panel of 6 judges.

Fresh experimental ice creams made using sago and cream flavour was equivalent to control ice cream in term of flavour. The experimental ice cream prepared with use of sago and butterbuds statistically has lower likings when compared with control. The experimental low fat ice cream having cream flavour was statistically more liked when compared with experimental low fat ice cream having butterbuds.

In terms of body and texture there were non significance difference observed between sago contained both the experimental samples and control. Sago was found to increase the viscosity of ice cream mix significantly, which might had been responsible for improving the body of ice cream.

The incorporation of sago in low fat vanilla ice cream was observed to have same melting characteristics as that of the normal (10 per cent) fat control ice cream. The melting quality of control ice cream and experimental low fat ice cream were statistically at par.

The values for colour and appearance for control and experimental ice cream were statistically at par. The values for low fat experimental samples have slight higher values compared to control.

The total sensory score of all the ice creams shows that all the ice creams had acceptable sensory quality. The total sensory score of low fat vanilla ice cream contain creamplus had significantly higher
values than that of control ice cream and low fat vanilla ice cream containing butterbuds. However, total sensory score of low fat vanilla ice cream containing butterbuds was significantly lower than that of the control ice cream.

It is concluded that use of sago in low fat ice cream can be done without any adverse effect on sensory attributes of normal fat control ice cream such as flavour, body and texture, melting quality, colour and appearance, and overall acceptability score while creamplus used in addition to vanilla flavourings. While instead of creamplus, butterbuds used the sensory scores for flavour and total sensory score had significantly lower values than control ice cream.

It could be concluded that sago can be used in low fat vanilla ice cream with addition of proper flavour enhancer; such ice cream can be comparable with normal fat ice cream in terms of flavour, body and texture, melting characteristics and colour and appearance as well as overall acceptability.

5.2.2 LOW FAT CHOCOLATE ICE CREAM USING SAGO:

There were two types of low fat chocolate ice creams prepared as prepared for the vanilla; one which was prepared using creamplus and other which was prepared using butterbuds to improve the flavour of low fat ice cream. These two low fat chocolate ice creams were compared with normal fat chocolate ice cream. The results were discussed under three main categories: chemical composition, physical properties and sensory evaluation.
The level of cocoa powder 2.0 used for the chocolate ice cream was selected by primary trials. The sucrose level was decided by preliminary trials for chocolate ice cream which was 15.5 per cent. After taking preliminary trials 0.025 per cent level of stabilizer for chocolate ice cream was selected. Vanilla flavour 0.4 ml/Kg ice cream mix was found to enhance the chocolate flavour. The cocoa powder would impart its own fat in the ice cream. Care had to be taken that total fat content of low fat ice cream does not increase than the max. limit given by mandatory standards. The fat of low fat chocolate ice cream was standardized for 2.0 per cent.

The formulation of control chocolate ice cream was; Fat: 10.0 per cent, MSNF: 12.5 per cent, Sucrose: 15.5 per cent; Sodium alginate: 0.15 per cent; GMS: 0.2 per cent, cocoa powder: 2.0 per cent and vanilla flavour 0.4 ml/kg of ice cream mix.

5.2.2.1 Chemical composition:

Compositional parameters like fat, protein, reducing and non-reducing sugars, and total solids were studied.

The average value for the fat of controlled ice cream was 10.18 and for low fat ice cream were 2.07. The low fat ice cream contained significantly low fat than that of control ice cream.

The average value of protein in control ice cream was 5.15 while for low fat creamplus (T1) ice cream it was 5.57 and for butterbuds (T2) ice cream the value was 5.61.

---

Summary and conclusions
The reducing sugars of low fat ice cream were significantly higher than that of control ice cream. The low fat ice cream containing higher amount of MSNF was responsible for high values of reducing sugars. Non-reducing sugar content of low fat ice cream was not significantly differing from that of control ice cream.

Low fat ice cream had significantly low total solids content. Total solid content of low fat ice cream and average fat ice cream were within the PFA standard (2006) prescribed for low fat ice cream and normal ice cream respectively.

5.2.2.2 Physical properties:

Physical parameters like acidity, viscosity, overrun and melting resistance were studied.

The average value of acidity for control ice cream mix was 0.208 per cent LA, which was significantly low than experimental mixes T1 and T2 which had acidity value 0.215 and 0.214 respectively.

The control mix had the least viscosity after ageing (69.67 mPas). The viscosity of experimental mixes T1 and T2 was higher which were 84.5 mPas and 86 mPas respectively. Such increase in viscosity was found significant at each experimental mixes.

The overrun of control ice cream was slight higher than the low fat sago contained ice creams. The overrun values of all ice creams were non significant.

Summary and conclusions
The melting resistant for control ice cream, low fat chocolate ice cream with creamplus and low fat chocolate ice cream with butterbuds were 51.6, 44.2 and 44.75 per cent respectively. The values for melting resistance were statistically significant.

### 5.2.2.3 Sensory quality:

Sensory parameters viz. flavour, body and texture, melting quality, colour and appearance, and overall acceptability were studied.

Fresh experimental ice creams made using sago and cream flavour as well as low fat ice cream containing butterbuds was equivalent to control ice cream in term of flavour. The experimental ice cream prepared with use of sago and butterbuds was slightly higher likings when compared with control and low fat chocolate ice cream prepared with creamplus.

In terms of body and texture there were non significance difference observed between sago contained both the experimental samples and control.

The melting quality of control ice cream and experimental low fat ice cream were statistically at par. The average value of melting quality of experimental sample was slightly higher than that of control ice cream.
The colour and appearance of low fat experimental chocolate ice creams were significantly higher values than that of control chocolate ice cream. The average values were 3.938, 4.328 and 4.408 for control, experimental ice cream with creamplus and experimental ice cream with butterbuds respectively.

Overall acceptability score of low fat chocolate ice cream containing butterbuds had significantly higher values than that of control ice cream and low fat chocolate ice cream containing creamplus. The overall acceptability score of all the ice creams shows that all the ice creams had acceptable sensory quality.

5.2.3 LOW FAT MANGO ICE CREAM USING SAGO:

After low fat chocolate ice cream prepared using sago, it was tried with fruit flavour i.e. mango. Creamplus and butterbuds were used as in chocolate ice cream. The results were discussed under three main categories: chemical composition, physical properties and sensory evaluation.

Some minor changes were required when mango pulp was used at the level of 20 per cent in ice cream. In this case quantity of stabilizer was 0.025 per cent and sago 2.5 per cent, rests of ingredients were same as selected in tentative formulation discussed earlier.

The formulation of control mango ice cream was; Fat: 10.0 per cent, MSNF: 12.5 per cent, Sucrose: 13.0 per cent; Sodium alginate: 0.15 per cent; GMS: 0.2 per cent and mango pulp 20 per cent.
**5.2.3.1 Chemical composition:**

Compositional parameters like fat, protein, reducing and non-reducing sugars, and total solids were studied.

The average value for the fat of controlled ice cream was 10.25 and for low fat ice cream were 2.38. The low fat ice cream contains significantly low fat than that of control ice cream. The low fat ice creams significantly contained high protein while compared with control. The reducing sugars of low fat ice cream were significantly higher than that of control ice cream. Non-reducing sugar content of low fat ice cream was not significantly differing from that of control ice cream. Low fat ice cream had significantly low total solids content compared to control. All the values of total solids were above the mandatory standards.

**5.2.3.2 Physical properties:**

Physical parameters acidity, viscosity, overrun and melting resistance were studied.

The average value of acidity for control ice cream mix was 0.208 per cent LA, which was significantly lower than experimental mixes T1 and T2 which had acidity value 0.214 and 0.214 respectively.

The control mix had the least viscosity after ageing (70.67 mPas). The viscosity of experimental mixes T1 and T2 was higher which were 85 mPas and 85.67 mPas respectively.
The overrun of control ice cream was slight higher than the low fat sago contained ice creams. The overrun values of all ice creams were non significant.

All the experimental samples made using sago had significantly slower meltdown as compared to control. Both the experimental samples had nearly similar values for melting resistance.

The average value of acidity of control mix after addition of pulp was 0.507 which was slightly lower than average value of both low fat mixes which was 0.523. The acidity of mixes after addition of pulp was statistically not significant.

5.2.3.3 Sensory quality:

Sensory parameters viz. flavour, body and texture, melting quality, colour and appearance, and overall acceptability scores were studied.

Experimental ice creams made using sago were statistically equivalent to control ice cream in term of flavour. The experimental ice cream prepared with cream flavour was slightly higher likings when compared with control and low fat chocolate ice cream prepared with butterbuds. In terms of body and texture there were non significance difference observed between the experimental samples and control. The melting quality of control ice cream and experimental low fat ice cream were statistically at par. The average value of melting quality of experimental samples was slightly higher than that of control ice cream.
The average values were 4.048, 4.197 and 4.158 for control, experimental ice cream with creamplus and experimental ice cream with butterbuds respectively. All the values given for colour and appearance of mango ice cream by judges were statistically at par.

The Overall acceptability score of low fat mango ice cream contain creamplus have slightly higher values than that of control ice cream and low fat chocolate ice cream containing butterbuds i.e. 87.62, 86.91 and 85.69 respectively. The values for over all overall acceptability for all the ice cream were statistically at par.

5.3 HEAT SHOCK STUDY:

Assessing the effect of heat shock on sensory properties of the formulated low fat ice cream using sago as an ingredient, was important for forecasting its suitability in actual market conditions. Therefore, hardened ice cream meted out with heat shock treatment (Section 3.9) evaluated for sensory characteristics. The plain varieties of ice creams, vanilla had no effect of heat shock on sensory attributes while compare with control. Heat shock treatment had no adverse effect on the quality of low fat vanilla ice creams formulated by sago as functional ingredient.

5.4 COMMERCIAL TRIAL:

The commercial success of any new product developed depends on the consumer response. The recipe formulated in the present study was evaluated through a consumer survey conducted by selecting randomly 85 consumers.
The final formulated low fat sago contained ice cream was prepared in a direct expansion type batch freezer for commercial trial. For each flavour of low fat ice cream (vanilla, chocolate, mango) the low fat ice cream getting high score of sensory evaluation, out of butterbuds and creamplus was selected for final commercial trial. So for vanilla and mango low fat ice cream the ‘creamplus’ was selected for commercial trial, while for chocolate ice cream the ‘butterbuds’ was selected.

The total milk fat in low fat ice cream was only 2.4 per cent which was 76 per cent less compared to control ice cream. The low fat ice cream prepared in direct expansion type batch freezer gave overrun in between 90 to 95.

All the six samples were given to 85 consumers and evaluated for sensory characteristics. The consumers find no difference in low fat ice cream prepared with use of sago and average fat control ice cream. Even few of the customer liked more experimental product in terms of colour and appearance, melting quality and richness.

None of the consumers disliked the experimental low fat ice cream. Out of 85 consumers who judged the low fat ice cream 55.0 per cent rated it as excellent, 33.7 per cent rated it as very good and 11.3 per cent rated it as good.

5.5 COMPARISON OF ENERGY VALUE OF THE DIETETIC LOW FAT ICE CREAM WITH AN AVERAGE ICE CREAM:
The energy value of an average control ice cream mix was 185.62 cal/100g. The energy value of the formulated dietetic low fat ice cream was 130.04 cal/100g. It represents a 30 per cent reduction in calorie.

5.6 COMPARISON OF COST OF RAW INGREDIENTS OF LOW FAT ICE CREAM WITH AN AVERAGE ICE CREAM:

There was 24.24 per cent reduction in the cost of raw material of the low fat ice cream when compared with control. The cost of one kg ice cream mix for vanilla flavour low fat ice cream was Rs.31.88 and for control average fat vanilla ice cream was Rs. 42.08.

From the present study it is concluded that sago can be used in low fat vanilla, chocolate and mango ice cream with addition of proper flavour enhancer; such ice cream can be comparable with normal fat ice cream in terms of flavour, body and texture, melting characteristics, and colour and appearance as well as overall acceptability. The low fat ice cream gives 30 per cent reduction in calorie compared to normal fat ice cream. In addition the resultant low fat ice cream gives cost reduction of Rs. 24.24 per cent compared to that of the normal fat ice cream.
REFERENCES


References


with different substitution levels of arrowroot powder for MSNF. *J. Food Sci. Technol.*, 27:390.


## APPENDIX I

**AVERAGE COMPOSITION OF DAIRY PRODUCTS EMPLOYED IN PREPARATION OF ICE CREAM MIXES**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mixed milk</th>
<th>cream</th>
<th>Skimmed milk</th>
<th>Skimmed milk powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat (%)</td>
<td>5.9 ± 0.23</td>
<td>69.4 ± 4.18</td>
<td>0.1 ± 0.1</td>
<td>0.85 ± 0.12</td>
</tr>
<tr>
<td>SNF (%)</td>
<td>8.8 ± 0.17</td>
<td>2.95 ± 0.19</td>
<td>9.1 ± 0.23</td>
<td>94.98 ± 0.14</td>
</tr>
<tr>
<td>Total milk solids</td>
<td>14.7 ± 0.2</td>
<td>72.35 ± 4.7</td>
<td>9.2 ± 0.23</td>
<td>95.83 ± 0.19</td>
</tr>
<tr>
<td>Acidity (%LA)</td>
<td>0.17 ± 0.02</td>
<td>0.058 ± 0.002</td>
<td>0.18 ± 0.02</td>
<td>0.97 ± 0.38</td>
</tr>
<tr>
<td>Solubility index (ml)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.48 ± 0.04</td>
</tr>
</tbody>
</table>
## APPENDIX II

### ICE CREAM SCORE CARD

*Replication/Trial No.:   *

<table>
<thead>
<tr>
<th>Perfect score</th>
<th>Criticisms</th>
<th>Sample No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td><strong>FLAVOUR (45)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal range  (31-40)</td>
<td>- Cooked</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lacks fine flavour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Too high flavour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lacks flavouring</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lacks freshness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Lacks sweetness</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Too sweet</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Metallic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Old ingredient</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Oxidized</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Rancid</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Salty</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Storage</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Syrup flavour</td>
<td></td>
</tr>
<tr>
<td><strong>BODY AND TEXTURE (30)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal range  (25-30)</td>
<td>- Coarse or icy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Crumbly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Fluffy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Soggy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Sandy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Weak</td>
<td></td>
</tr>
<tr>
<td><strong>MELTING QUALITY (5)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal range  (4-5)</td>
<td>- Curdy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Does not melt</td>
<td></td>
</tr>
<tr>
<td><strong>COLOUR (5)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>- Colour uneven</td>
<td></td>
</tr>
<tr>
<td>Defect</td>
<td>Slight</td>
<td>Definite</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td><strong>Flavour</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooked</td>
<td>39</td>
<td>37.5</td>
</tr>
<tr>
<td>Egg</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td>High acid</td>
<td>36</td>
<td>34</td>
</tr>
<tr>
<td>Lacks fine flavour</td>
<td>39.5</td>
<td>38.5</td>
</tr>
<tr>
<td>Lacks flavouring</td>
<td>39.5</td>
<td>38.5</td>
</tr>
<tr>
<td>Lacks fressness</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td>Lacks sweetness</td>
<td>39</td>
<td>38.5</td>
</tr>
<tr>
<td>Metallic</td>
<td>36.5</td>
<td>34.5</td>
</tr>
<tr>
<td>Neutralizer</td>
<td>36.5</td>
<td>33.5</td>
</tr>
<tr>
<td>Old ingredient</td>
<td>37</td>
<td>35.5</td>
</tr>
<tr>
<td>Oxidized</td>
<td>37</td>
<td>34.5</td>
</tr>
<tr>
<td>Rancid</td>
<td>35</td>
<td>33</td>
</tr>
<tr>
<td>Salty</td>
<td>38</td>
<td>35.5</td>
</tr>
<tr>
<td>Storage</td>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>Too high flavour</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td>Too sweet</td>
<td>39</td>
<td>38</td>
</tr>
<tr>
<td>Unclean</td>
<td>35</td>
<td>33.5</td>
</tr>
<tr>
<td>Unnatural flavouring</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>Unnatural sweeter</td>
<td>38</td>
<td>37</td>
</tr>
<tr>
<td><strong>BODY AND TEXTURE</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse</td>
<td>29</td>
<td>28</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Requirement</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>Moisture, percent by wt., Max</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Total ash (dry basis), percent by wt. max.</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td>Acid insoluble ash (dry basis), percent by wt. max.</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Starch (dry basis), percent by wt. min.</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>Protein (N*6.25) (dry basis), percent by wt. max.</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>Sulphur dioxide, ppm, max</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Crude fiber (dry basis, percent by wt. max.</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td>pH of aqueous extracts</td>
<td>4.5 to 7.0</td>
<td></td>
</tr>
</tbody>
</table>
9. Colour of gelatinized alkaline paste in the porcelain cuvette on the Lovibond Scale, not deeper than

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Name of Additives</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(A) Stabilizers singly or in combination</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Carrageenan</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>2</td>
<td>Pectins</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>3</td>
<td>Sodium carboxy methyl cellulose</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>4</td>
<td>Agar</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>5</td>
<td>Guar gum</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>6</td>
<td>Xanthan gum</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>7</td>
<td>Furcellaran</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>8</td>
<td>Propylene glycol alginate</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>9</td>
<td>Poly glycerol esters of fatty acids</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>10</td>
<td>Mono- and diglycerides of fatty acids</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td>11</td>
<td>Methyl cellulose</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td></td>
<td>(B) Thickene and Modifying Agents</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Micro- crystalline cellulose</td>
<td>Max. 10 g/Kg</td>
</tr>
<tr>
<td></td>
<td>(C) Modified starches singly or in combination</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Acid- treated starch</td>
<td></td>
</tr>
</tbody>
</table>

APPENDIX V

FOOD ADDITIVES FOR USE IN ICE CREAM/KULFI/DRIED ICE CREAM MIX/FROZEN DESSERTS/MILK ICES/ MILK LOLLIES/ICE CANDY
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Alkline-treated starch</td>
<td>Max. 30 g/Kg</td>
</tr>
<tr>
<td>3</td>
<td>Bleached starch</td>
<td>subject to declaration</td>
</tr>
<tr>
<td>4</td>
<td>Acetylated distarch adipate</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Distarch glycerol</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Acetylated distarch glycerol</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Hydroxypropyl distarch glycerol</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Distarch phosphate</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Acetylated distarch phosphate</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Hydroxypropyl distarch phosphate</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Oxidized starch</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Starch acelate</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Hydroxypropyl starch</td>
<td></td>
</tr>
</tbody>
</table>

(D) Flavours

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Natural flavouring and natural flavouring substances/Nature identical flavouring substances/artificial flavouring substances</td>
<td>GMP subject to declaration</td>
</tr>
</tbody>
</table>

(E) Colours (Natural- singly or in combination)

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Curcumin</td>
<td>Max. 100 mg/Kg</td>
</tr>
<tr>
<td>2</td>
<td>Riboflavin</td>
<td>Max. 50 mg/Kg</td>
</tr>
<tr>
<td>3</td>
<td>Beta Carotene</td>
<td>Max. 100 mg/Kg</td>
</tr>
<tr>
<td>4</td>
<td>Annatto extracts on bixin/norbixin basis (50:50 ratio)</td>
<td>Max. 100 mg/Kg</td>
</tr>
<tr>
<td>5</td>
<td>Beta apo carotenal</td>
<td>Max. 100 mg/Kg</td>
</tr>
<tr>
<td>6</td>
<td>Methyl ester of Beta apo8 carotenoic acid</td>
<td>Max. 100 mg/Kg</td>
</tr>
<tr>
<td>7</td>
<td>Canthaxanthinin</td>
<td>Max. 100 mg/Kg</td>
</tr>
<tr>
<td>8</td>
<td>Caramal colours (Plain)</td>
<td>GMP</td>
</tr>
<tr>
<td>9</td>
<td>Caramal colours (Ammonium sulphite process)</td>
<td>Max. 3.0 g/Kg</td>
</tr>
<tr>
<td>10</td>
<td>Ponceau 4R, Carmoisine, Erythrosine, Tartrazine, Sunset Yellow FCF, Indigo carmine, Brilliant Blue FCF, Fast Green</td>
<td>Max. 100 mg/Kg</td>
</tr>
<tr>
<td></td>
<td>Acidifying Agents singly or in combination</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>GMP including sod/pot salts</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Citric acid</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Acetic acid</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Lactic acid</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Malic acid (DL-)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Tartaric acid &amp; Sodium/Potassium salts</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Sodium Hydrogen Carbonate</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Sodium/Potassium/Calcium</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Orthophosphate expressed as $P_2O_5$</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Sodium/Potassium Polyphosphate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>expressed as $P_2O_5$</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>Miscellaneous</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Glycerol</td>
<td></td>
</tr>
</tbody>
</table>

Max. 1 g/Kg

Max. 2 g/Kg

Max. 50 mg/Kg
THAI CASSAVA STARCH

Physically modified starch
- Pregelatinized starch
- Heat-Moisture treated starch
- Sago pearl or tapioca pearl

Chemically modified starch
- Acid thinned starch
- Dextrinized starch
- Oxidized starch
- Starch eather
  - Hydroxy-propyl starch
- Starch eather
  - Starch Octenylsuccinate
  - Acetyl starch
  - Phosphate mono-ester starch
- Cross linked starch
  - Di-starch phosphate
- Dual -modification
  - Hydroxy-propyl distarch phosphate
  - Acetylated distarch adipate
  - Acetylated distarch phosphate

Hydrolyzed starch & Derivatives
- Maltodextrin
- Sweeteners
  - Glucose
  - Fructose
- Polyols
  - Sorbitol
  - Mannitol
- Amino acid
  - Glutamate
  - Lysine
- Organic acid
  - Citric acid

(Sriroth et al. 2002)

APPENDIX VI: MODIFIED CASSAVA STARCH AND DERIVATIVES CURRENTLY AVAILABLE IN MARKET
EXPERIMENTAL ICE CREAM WITH SAGO & BUTTERBUDS

CONTROL ICE CREAM
PLATE 11: SAGO CONTAINING LOW FAT AND REGULAR FAT CONTROL CHOCOLATE ICE CREAMS MANUFACTURED COMMERCIALY
PLATE 12: SAGO CONTAINING LOW FAT AND AVERAGE FAT CONTROL MANGO ICE CREAMS MANUFACTURED INDUSTRIALLY
EXPERIMENTAL ICE CREAM WITH SAGO & CREAMPLUS

CONTROL ICE CREAM

PLATE 10: SAGO CONTAINING LOW FAT AND AVERAGE FAT CONTROL VANILLA ICE CREAMS MANUFACTURED INDUSTRIALLY
PLATE 2: FLAVOURING MATERIALS i.e. COCOA POWDER, ALPHONSO MANGO PULP AND BUTTERBUDS
PLATE 9: MANGO FLAVOURED CONTROL AND SAGO CONTAINING LOW FAT ICE CREAMS
PLATE 5: VANILLA FLAVOURED CONTROL AND SAGO CONTAINING LOW FAT ICE CREAMS
PLATE 6: MELTING QUALITY OF

STAGE: 1

STAGE: 2

A: EXPERIMENTAL ICE CREAM WITH SAGO & CREAMPLUS
B: EXPERIMENTAL ICE CREAM WITH SAGO & BUTTERBUDS
C: REGULAR FAT CHOCOLATE ICE CREAM (CONTROL)

CHOCOLATE ICE CREAMS
A: EXPERIMENTAL ICE CREAM WITH SAGO AND CREAMPLUS; B: EXPERIMENTAL ICE CREAM WITH SAGO AND BUTTERBUDS; C: CONTROL MANGO ICE CREAM

PLATE 8: MELTING QUALITY OF MANGO ICE CREAMS
A: EXPERIMENTAL ICE CREAM WITH SAGO & CREAMPLUS
B: EXPERIMENTAL ICE CREAM WITH SAGO & BUTTERBUDS
C: CONTROL VANILLA ICE CREAM

PLATE 4: MELTING QUALITY OF VANILLA ICE CREAMS
SAGO PEARLS OR TAPIOCA PEARLS OR SABOODANA

SACHAMOTI BRANDED AGMARK STANDARD TAPIOCA SAGO

PLATE 1: SAGO USED IN THE INVESTIGATION