# RHEOLOGICAL PROPERTIES OF HEAT-AND-ACID COAGULATED INDIAN MILK PRODUCTS

THESIS
SUBMITTED TO THE KURUKSHETRA UNIVERSITY, KURUKSHETRA
FOR THE DEGREE OF
**DOCTOR OF PHILOSOPHY**
IN DAIRY TECHNOLOGY

BY

**DESAI, HRADAYKUMAR K.**

DIVISION OF DAIRY TECHNOLOGY
NATIONAL DAIRY RESEARCH INSTITUTE
( I. C. A. R. )
KARNAL ( HARYANA ) INDIA
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**DR. SUDHIR K. GUPTA,**
Ph.D.(Illinois)
Associate Dean-cum-Director
Sanjay Gandhi Institute of Dairy Technology
Rajendra Agricultural University,
PATNA-800 020.

DAIRY TECHNOLOGY DIVISION
NATIONAL DAIRY RESEARCH INSTITUTE
(I.C.A.R.)
KARNAL - 132001.

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I certify that the work reported in this thesis entitled **"RHEOLOGICAL PROPERTIES OF HEAT-AND-ACID COAGULATED INDIAN MILK PRODUCTS"** was carried out by Mr. DESAI, HRADAYKUMAR KUNJBIHARI under my guidance, as the requirement for the Degree of DOCTOR OF PHILOSOPHY in the Faculty of Dairying, Animal Husbandry and Agriculture, Kurukshetra University, Kurukshetra.

**(SUDHIR K. GUPTA)**

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(H.K. DESAI)

# C O N T E N T S

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| BOD | Biological Oxygen Demand |
| BP | British Pharmacopoeia |
| DRBC | Buffalo milk chhana as per De and Ray (1954) |
| ICBC | Buffalo milk chhana (0.05% sodium citrate) as per Iyer (1978) |
| IBC | Buffalo milk chhana (25% water addition) as per Iyer (1978) |
| KSBC | Buffalo milk chhana as per Kumar and Srinivasan (1982) |
| KDBC | Buffalo milk chhana as per Kundu and De (1972) |
| SBC | Buffalo milk chhana as per Soni *et al.* (1980) |
| BBP | Buffalo milk paneer as per Bhattacharya *et al.* (1971) |
| RBP | Buffalo milk paneer as per Rao *et al.* (1984) |
| SBP | Buffalo milk paneer (0.1% sodium alginate) as per Sachdeva (1983) |
| Ca | Calcium (%) |
| cm | Centimeter |
| r | Correlation coefficient, radius |
| BDC | Cow milk chhana as per Bhattacharya and Dasraj (1980a) |
| DRC | Cow milk chhana as per De and Ray (1954) |
| IC | Cow milk chhana as per Iyer (1978) |
| KSC | Cow milk chhana as per Kumar and Srinivasan (1982) |
| SDC | Cow milk chhana as per Sen and De (1984) |
| SC | Cow milk chhana as per Soni *et al.* (1980) |
| SCCP | Cow milk paneer (1g/l calcium chloride) as per Sachdeva *et al.* (1985) |
| SCP | Cow milk paneer (90°C coagulation without calcium chloride) as per Sachdeva *et al.* (1985) |

| | |
|---|---|
| CD | Critical Difference |
| $^{o}C$ | Degree celcius |
| dia | Diameter |
| DM | Dry Matter |
| F | Fat (%) |
| FDM | Fat in Dry Matter (%) |
| Fig | Figure |
| CLFPF | Fried and cooked CLFP paneer |
| BBPF | Fried and cooked BBP paneer |
| MPF | Fried and cooked market paneer (1-6 represents vendor) |
| RBPF | Fried and cooked RBP paneer |
| SBPF | Fried and cooked SBP paneer |
| SCCPF | Fried and cooked SCCP paneer |
| SCPF | Fried and cooked SCP paneer |
| g | Gram |
| G | Gravitational force |
| GF | General Foods |
| h | Height |
| hr | Hour |
| IP | Indian Pharmacopoeia |
| ISI | Indian Standards Institution |
| Ch | Instron chewiness |
| Co | Instron cohesiveness |
| Gu | Instron gumminess |
| H | Instron hardness |
| Sp | Instron springiness |
| Kg | Kilogram |
| LR | Laboratory Reagent |

| | |
|---|---|
| l | Litre |
| CLFP | Low fat buffalo milk paneer as per Chawla (1981) |
| MC | Market chhana (1-6 represent vendor) |
| MP | Market paneer (1-6 represent vendor) |
| max. | Maximum |
| ug | Microgram |
| ml | Millilitre |
| mm | Millimeter |
| mN | Milli Newton |
| min. | Minute |
| DRMC | Mixed milk chhana as per De and Ray (1954) |
| IMC | Mixed milk chhana as per Iyer (1978) |
| SMC | Mixed milk chhana as per Soni et al. (1980) |
| Mo | Moisture (%) |
| M | Molarity |
| N | Newton, Normality |
| NL | Normal Rasogolla |
| PFA | Prevention of Food Adulteration |
| PR | Protein (%) |
| PRDM | Protein in Dry Matter (%) |
| RBD | Randomized Block Design |
| SCH | Sensory chewiness |
| SCR | Sensory crumbliness |
| SE | Sensory elasticity |
| SF | Sensory firmness |
| SJU | Sensory juiciness |
| SOTQ | Sensory overall textural quality |
| SSM | Sensory smoothness |

| | |
|---|---|
| SST | Sensory stickiness |
| SL | Small Rasogolla |
| SNF | Solids-not-fat |
| SG | Sponge Rasogolla |
| SS | Stainless steel |
| TPA | Texture Profile Analysis |
| V | Volume |
| W | Weight |

# INTRODUCTION

# INTRODUCTION

(Texture, which is an important fundamental sensory property of all foods, can be regarded as a manifestation of the rheological properties of a food. de Man (1980) defined food texture as "the way in which the various constituents and structural elements are arranged and combined into a micro-and macro-structure, and the external manifestations of this structure in terms of flow and deformation".] The structural organization of food, thus, is influenced by chemical composition and various physical forces, whereas the external manifestation of food structure is related to the mechanical (rheological) and sensory textural properties of the food. Texture is an important quality attribute as it affects processing and handling (Charm, 1962) and influences shelf life, consumer acceptance and food habits] (Matz, 1962). Present information indicates that the consumer is highly conscious of food texture, and that in certain foods, texture may even be more important than flavour (Szczesniak and Kleyn, 1963).

(The study of texture is important to establish mechanical behaviour of a food when consumed. The characteristics of perceived "texture" are determined by different physical and physico-chemical properties of food and by the unique as well as complex features of the human sensory systems (Peleg, 1987). The knowledge of some of the rheological properties of a food may give important clues to its acceptability and may be of utmost importance in determining the nature and design of processing methods and equipment (de Man, 1980), and for predicting the product quality under certain manufacturing conditions.) However, this does not entail that rheology is the sole key to understanding texture, as there is ample evidence that geometrical, chemical, thermal, acoustic and psychological factors can also play a major role in sensory textural assessment (Peleg, 1987).

Most foods are complex materials, structurally and rheologically. In many instances they consist of mixtures of solids as well as fluid structural components. Many foodstuffs are neither homogeneous nor isotropic but have properties that vary from one point to another within their mass (Finney, 1973). In many cases, foods are chemically active and physically unstable. Because of these reasons even if we attempt only to deal with rheological aspects of food texture evaluation, enormous difficulties arise as the related theories were originally developed for engineering materials which are homogenous and stable (Peleg, 1987).

(Sensory evaluation of texture in foods belongs to the domain of psychology known as psychophysics. Psychophysics directly concerns the correlation of sensory experience with physical measures (Moskowitz *et al.*, 1973). Relating instrumental methods with manual operations, relying mostly on available local inputs. Although, during the last three decades, studies have been carried out in order to optimize the processing and storage conditions in relation to chhana and paneer. Attempts have been made to mechanize chhana production (Aneja et al., 1982). However, the area of rheology of chhana, Rasogolla and paneer has remained practically unexplored. Therefore, this study was undertaken with following objectives in mind:

a) To elucidate the rheological and sensory textural properties of market samples of heat-and-acid coagulated Indian indigenous milk products viz. chhana and paneer, and products based on them viz., Rasogolla and Sandesh.

b) To assess the rheological and sensory textural properties of chhana and paneer prepared according to different methods reported in literature.

c) To determine the effect of composition on the rheological characteristics of chhana and paneer.

d) To correlate objective data (instrumental) with subjective (sensory) data on texture of these products so as to enable prediction of the latter from the former.

# REVIEW

# OF

# LITERATURE

# 2 REVIEW OF LITERATURE

This chapter deals with the pertinent literature surveyed, covering the following aspects:

1. Food texture terminology
2. Instrumental measurement of food texture
3. Sensory measurement of food texture
4. Interrelationship between instruments and sensory assessment of food texture
5. Texture of dairy products
6. Texture of heat-and-acid coagulated Indian milk products
7. Texture of chhana-based sweets

Food rheology is mainly concerned with forces and deformations; however, time and temperature are also important factors affecting rheological phenomena (de Man, 1980). Since the application of force results in deformation (and vice-versa), these two phenomena are considered together. True solids generally display time-independent deformations, while liquids show time-dependent deformations under applied forces (Finney, 1973). Deformations may be of one or both of two types, irreversible deformation called flow and reversible deformation called elasticity. The work used in the former is dissipated as heat and body is permanently deformed, whereas in case of reversible deformation it is recovered upon release of the deforming stress when the body regains its original shape (de Man, 1980).

Stress is the intensity factor of force and is expressed as force per unit area (de Man, 1980). There are a number of types of stresses. Three most commonly applied stresses are: compressive, tensile and shearing. In most real bodies, the application of external force will result in different kinds of internal stresses eg. bending involves all three, tension, compression and shear. Stress-strain relationships within a material, however, are related to structure and depend upon the manner in which the material responds to force or to an imposed deformation (Finney, 1973). The ratio of stress and strain is called "modulus", and hence, compression modulus, tensile modulus or shear modulus. When an elastic material is compressed, the stress strain plot is a straight line at the origin and its slope is called "Young's modulus of elasticity". Many foods exhibit this behaviour under small compressions before the so called "limit of elasticity" is reached. The maximum stress that the material is capable of sustaining, before rupture, is called "strength", designated by the respective type of stress (Szczesniak, 1983).

Rheological studies relating stress to strain within materials may be broadly considered under the headings of elasticity, viscosity and plasticity, and various combinations of the three to account for overlapping behaviours such as visco-elastic or elasto-plastic behaviour (Finney, 1973). These behaviours indicate the response of a material to force and deformation. The assessment of food texture is, in part, based on these responses under various test conditions. Microstructural and compositional analyses further aid in the assessment of texture.

## 2.1 FOOD TEXTURE TERMINOLOGY

### 2.1.1 Specific Textural Characteristics

In spite of the widespread use of the word texture and other terms to describe specific textural attributes of foods, there are still no internationally accepted definitions of such terms. This lack of standardization in texture terminology can lead to difficulty in interpreting the results from consumer surveys and trained sensory panels.

Even with well established texture definitions, problems arise in translating these to measurable properties (Szczesniak, 1963). Szczesniak (1963) classified textural properties into three main groups, namely (i) mechanical properties, (ii) geometrical properties, and (iii) other properties (such as moisture and fat content). Mechanical characteristics were further divided into five primary parameters (hardness, cohesiveness, viscosity, elasticity and adhesiveness) and three secondary parameters, namely, fracturability (brittleness), gumminess and chewiness, which are products of two or more primary properties. Elasticity was later defined as springiness (Bourne, 1969). Primary properties, except adhesiveness, measure the response of food to stress and are related to the ability of food to resist disintegration under applied force (Szczesniak, 1963).

Geometric characteristics refer to the arrangement of the constituents of the food including the size and shape of particles as well as particle orientation. Therefore, the gross- and micro-structure of the food will determine its geometrical properties. Other characteristics, such as moisture and fat content, describe the chemical composition of the food and are closely related to mouthfeel. They also contribute to phenomena observed during instrumental analysis, such as lubricating ability.

The physical and sensory definitions of mechanical characteristics were given in parallel by Civille and Szczesniak (1973) and have been accepted for texture profile analysis in recent times. The same has been presented in Table 2.1. Jowitt (1974) published in detail the terminology of food texture which includes definitions for the terms texture, structure and consistency in relation to sensory assessment.

### 2.1.2 Sensory Texture Profile

Sensory texture profile was defined by Brandt _et al._ (1963) as "the organoleptic analysis of the texture complex of a food in terms of its mechanical, geometrical, fat and moisture characteristics, the degree

Table 2.1 Definitions of Textural Characteristics

| Properties | Physical | Sensory |
|---|---|---|
| **Primary:** | | |
| Hardness | Force necessary to attain a given deformation | Force required to compress a substance between teeth |
| Cohesiveness | Extent to which a material can be deformed before rupture | Degree to which a substance is compressed between the teeth before it breaks |
| Viscosity | Rate of flow per unit force | Force required to draw liquid over the tongue |
| Springiness | Rate at which a material returns to its original condition | Degree to which a product returns to its original shape |
| Adhesiveness | Work necessary to overcome the attractive forces between the surface of the food and the contact plate | Force required to remove the material that adheres to the mouth during eating |
| **Secondary:** | | |
| Fracturability | Force with which a material fractures | Force with which a sample crumbles or cracks |
| Chewiness | Energy required to masticate a food to a state ready for swallowing | Time required to masticate the sample to a state ready for swallowing |
| Gumminess | Energy required to disintegrate a semisolid food to a state ready for swallowing | Denseness that persists throughout mastication |

Source: Civille and Szczesniak (1973)

of each present, and the order in which they appear from first bite thruugh complete mastication".

Szczesniak and her co-workers (Szczesniak, 1963; Szczesniak *et al.*, 1963, and Brandt *et al.*, 1963) proposed a sensory texture profile while developing a standardized methodology for evaluating the sensory texture of foods, which was modified by Sherman (1969) as shown in Fig. 2.1

There are many applications of sensory texture profiling, mainly in product development and quality control. It is extremely useful when objective methods are not available.

### 2.1.3 Objective Texture Profile

The understanding that texture is composed of several inter-related parameters led to the development of a texture profile which accounted for changes in texture as a result of force, time and temperature variations (Larmond, 1976). The texture profile was originally designed for mechanical assessment of texture based on sensory and objective measurements (Szczesniak *et al.*, 1963) and uses the classification of primary and sedondary properties described earlier.

The instrumental texture profile attempts to quantify as many textural parameters as possible (Larmond, 1976). Based on the concept that some textural characteristics (especially the mechanical ones) could be measured instrumentally, the General Foods Texturometer

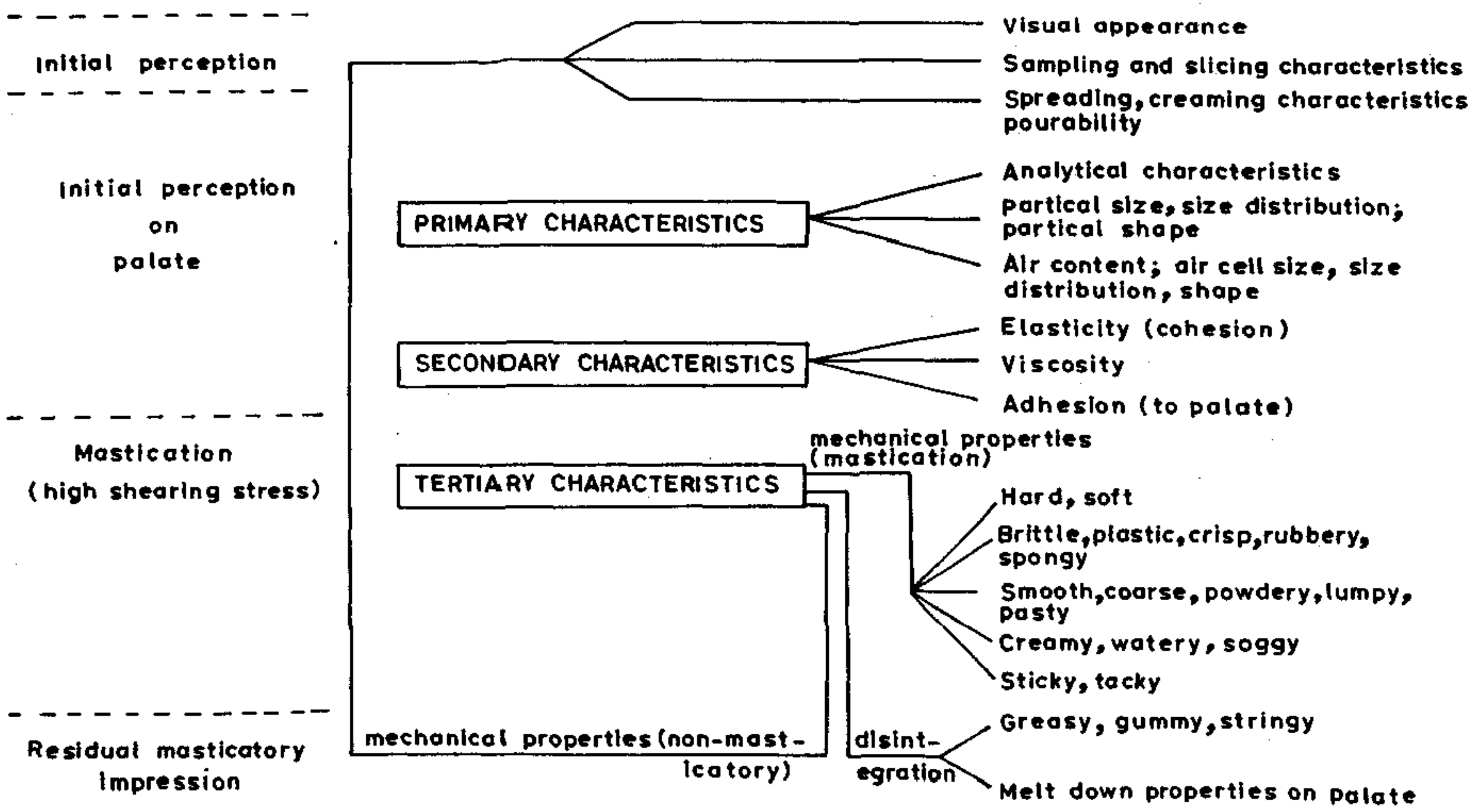


FIG. 2.1 THE MODIFIED TEXTURE PROFILE

(SOURCE: SHERMAN, 1969)

was designed as a comprehensive objective method for characterizing food texture (Larmond, 1976). This instrument described by Friedman et al. (1963) was designed to imitate the way force is applied in the mouth. Forces are recorded on a strip-chart recorder and a typical texture profile curve is obtained.

Bourne (1968) developed a method of evaluating texture profile parameters with Instron Universal Testing Machine. Instron consists of a drive unit, which drives a horizontal cross-unit in a vertical direction, and a force-sensing and recording system consisting of a series of interchangeable load-cells, the output from which is fed to a chart recorder. Food specimens are compressed twice to preselected levels of deformation (to imitate first two bites), which results into a typical curve of the first and second bite.

## 2.2 INSTRUMENTAL MEASUREMENT OF FOOD TEXTURE

Instrumental evaluations of textural properties is a complex problem, particularly, as the mechanics of evaluating rheological properties of foods is dependent upon a variety of test conditions such as rate of loading, the magnitude of deformations imposed upon the material, geometry of the loading surface, and localized yielding within the product tested (Finney, 1969).

Over the years literally hundreds of instruments have been developed for the measurement of mechanical properties of foods. Many of these were designed specifically for a single food product or commodity. More recently, instruments of wider applicability have become available.

Multiple-purpose instruments such as Allo-Kramer shear press, the General Food Texturometer and the Instron Universal Testing Machine have gained considerable popularity in recent years because of their versatility, flexibility, accuracy and appealing design features. Instron Universal Testing Machine has been used increasingly for Texture Profile Analysis (TPA) measurements since the studies of Bourne (1968). Parallel plate uniaxial compression using Instron to obtain force-deformation curve is commonly used for food texture investigations (Olkku and Sherman, 1979).

The Instron Universal Testing Machine is composed of a mechanical drive system, a load cell to measure forces generated either in compression or tension, a recorder, and a set of controls to automate the performance of the unit and introduce considerable flexibility and versatility. The mechanical drive system consists of a variable speed horizontal crossbar (called the crosshead) driven vertically up and down. The recorder chart is driven by a synchronous motor through a set of gears. These can be the same or different from the crosshead gears, thus allowing the expansion or contraction of the distance axis. In addition, the instrument can be preset for maximum distance or maximum load at which the movement of crosshead stops; it can be programmed for automatic returns, cycling, relaxation tests etc. (Szczesniak, 1973).

### 2.2.1 Compression Testing with Instron

The behaviour of foods in compression is one of the easiest and most important mechanical tests to perform (Szczesniak, 1983), and therefore, parallel plate uniaxial compression using an Instron to obtain force-deformation curve is commonly used for texture evaluations. In most uniaxial compressive tests, a food specimen, usually a cylinder or cube, is deformed at a constant deformation rate and mechanical parameters are quantified from the force-deformation curve (Peleg, 1987).

It is evident that compression testing data for food materials which do not specify sample dimensions, and test conditions such as deformation speed and the degree of deformation in cyclic testing, are in most cases inadequate. Szczesniak (1968) also noted that instrumental results were affected by test conditions, data interpretation and homogeneity of the test material.

2.2.1.1 Test Conditions: If reported conditions of obtaining TPA parameters are anything, they are inconsistent among different workers and food products. A major reason for inconsistency lies in the obvious differences which exists among different foods as to size of the largest unit, shape, homogeneity of structure and composition (Breene, 1975). Effects of different test conditions on cheeses have been reported in the literature by several workers (Sherman, 1976; Vernon Carter and Sherman, 1978; Lee _et al_., 1978; Chen _et al_., 1979; Gupta _et al_., 1984; Green _et al_., 1985; Casiraghi _et al_., 1985; and Shinin, 1987). Lee _et al_. (1978) found that the magnitude of response to various test conditions, particularly temperature, varied according to the type of cheese studied.

2.2.1.1.1 Sample Size and Shape: Sample size and shape have varied considerably in literature-standard size cubes, cylinders, discs or rectangularly shaped samples have been used for compression testing (Breene, 1975). In general, cylindrical or cubical sample with flat, surface is most common for food specimen (Olkku and Sherman, 1979; Peleg, 1987).

Theoretically, in a perfect test on an ideal material the stress-strain relationship in uniaxial deformation ought to be independent of the specimen dimensions by definition. In practice, especially in compressive tests of relatively flat specimens (i.e. height-to-width or height-diameter ratio of about unity or less), this is not always so, mainly because:

(1) friction forces along the contact surfaces can become significant and, consequently, the specimen will exhibit considerably higher apparent strength and probably a different deformability pattern; several workers have

suggested lubrication or other modification of the plates (Culioli and Sherman, 1976; Montejano *et al*., 1963; Casiraghi *et al*., 1985; Bagley *et al*., 1985a,b; and Shinin, 1987), (2) many food materials are fluid containing structures; in many cases, the stress level in a deformed specimen taken from such material is largely a result of hydrostatic pressure build-up (Peleg, 1987).

2.2.1.1.2 Size of Compressing Unit Vs Sample: The size of the compressing unit (sometimes referred to as the "punch" or "probe") with respect to sample which often varies and also affects the results. When the compressing unit is larger than the sample, the recorded forces are due largely to compression. However, when the opposite is true, the forces derive largely from a combination of compression and shear (Breene, 1975).

2.2.1.1.3 Percent Compression: Friedman *et al*. (1963) specified that the sample be deformed to one-fourth its original height (i.e. 75% deformation) in each of the two bites. Although most workers have used 75 to 80 per cent compression (Gupta *et al*., 1984), a range of 10 to 90 per cent compression has been used (Shama and Sherman, 1973a,b).

Bourne and Comstock (1981) studied the effect of degree of compression on texture profile parameters of various products including cream cheese reported that while fracturability was almost independent of the degree of compression, hardness, cohesiveness, gumminess and chewiness usually increased with increasing compression but the rate of increase varied widely.

Shinin (1987) employing double cycled compression, applied 25%, 50% and 75% compressions to a flat, cylindrical test samples of cheese. He observed that level of compression was most significant for variations in springiness, chewiness and adhesiveness. Variety of cheese was most important in determining the effect of percent deformation on fracturability. He concluded that acceptable levels of variations were noted when cheese texture was evaluated under levels of strain that did not greatly exceed the fracture or yield value of the cheese. Although fracture may be of critical importance in many foods, Mohsenin (1977) and Mohsenin and Mittal (1977) believed that non-destructive small strain tests may also be very valuable.

2.2.1.1.4 Crosshead Speed: Shama and Sherman (1973a,b) pointed out that the crosshead speed has usually been selected at random. They cited nine examples of compression tests on food with the Instron wherein crosshead speed ranged from 0.2 to 5.0 cm. $min^{-1}$.

2.2.1.1.5 Temperature: The physical properties of foods are extremely sensitive to changes in environmental conditions such as temperature and moisture (Finney, 1969). Temperature of specimen under specified test conditions for instrument is of great importance. Many products show important changes in rheological behaviour as a result of changes in temperature (de Man, 1980).

Awadhwal and Singh (1985), while developing a rheological model for paneer, used 15$^{o}$C temperature for Instron measurements.

2.2.1.1.6 Number of Bites: Most GF TPA work has utilized two bites. However, one bite is sufficient to provide values for brittleness and hardness (Breene, 1975). Shama and Sherman (1973a, b) used only one bite in seeking optimum conditions for hardness. As pointed out by Breene (1975) when all the parameters of TPA are desired, two bites are necessary; when only one or some are desired, one bite may be sufficient.

## 2.3 SENSORY MEASUREMENT OF FOOD TEXTURE

Sensory evaluation is extremely valuable in the measurement of food texture because no instrument can perceive, analyze, integrate and interpret a large number of textural sensations at the same time. The pleasure centre in the brain plays a very important role in sensory evaluation. Even with strictly trained panels, which attempt to be as analytical and objective as possible, sensory evaluation often gives important information on psychological reaction to the product (Larmond, 1976).

Szczesniak (1963) linked texture to sensory, structural and physical parameters. Corey (1970) stated texture to be but another name for the interaction of the human senses with the mechanical properties of the material. Sherman (1970), in a modification of Szczesniak (1963 ) definition, expressed "testure as the composite of those properties arising from the structural elements, and the manner in which they register with the physiological senses".

Jowitt (1974) stated that the appreciation of texture involves the subtle interaction between both motor and sensory components of the masticatory and central nervous systems. In other words, the complex reactions caused during the chewing of food are all taken into account by the brain in a comprehensive description of texture.

### 2.3.1 Perception of Texture

The relation between physical input into the human sensory system and what is actually perceived has not been studied thoroughly (Larmond, 1976). According to Matz (1962) the senses responsible for texture perception are: (i) those in the superficial structure of the mouth, the hard and soft palate, tongue and gums; (ii) those around the roots of the teeth in a periodontal membrane; and (iii) those in the muscles and tendons used in mastication.

As stated by Boyar and Kilcast (1986) the neurological basis of oral perception involves stimulation of atleast several sensory systems. Food is a tactile stimulus to the tongue, palate and pharyngeal regions and chewing, through movement of both jaw and the tongue, is the cause of muscular sensation. Oral perception also involves olfactory, taste and pain neuroreceptors.

Textural characteristics are perceived in four stages: (1) Initial perception (visual appearance, spreading, creaming characteristics etc.); (2) Initial perception on palate characteristics etc. (primary and secondary properties); (3) during mastication (properties derived from two or more sensory attributes) and (4) a residual masticatory impression (include oiliness or greasiness and coating of the palate) (Larmond, 1976).

It is well known and has long been recognized that the fingers, tongue and jaws have different sensitivities to textural properties. In part, this ought to be due to the obvious differences in the sensing mechanism; i.e., the extent to which mechanical, thermal, acoustical, and chemical stimuli are involved in the overall physiological response and sensory perception (Peleg, 1980).

Basic principles of sensory evaluation, sensory panels, testing environment, sample preparation, method of presentation, sensory methods, sensory perception and scales of magnitude have been discussed in detail by Amerine et al. (1965), Birch et al. (1977), Piggott (1984) and Jellinek (1985).

Sensory measurement of food texture has been dealt with in detail by Moskowitz et al. (1972), Larmond

(1976), and Brennan (1984). Szczesniak and Bourne (1969) examined non-oral sensory methods used by consumers to assess firmness.

## 2.4 INTERRELATIONSHIP BETWEEN INSTRUMENTS AND SENSORY ASSESSMENT OF FOOD TEXTURE

Over the past two decades, scientists have sought to map the relations between physical properties of foods and the subjective perception of textural responses (Moskowitz and Jacob, 1987). Well defined measurements of the mechanical properties of food and the reduction of sensory attributes into fundamental primary entities, together with the functions which interrelate them, provide the basis for the eventual development of instruments calibrated in terms of human sensory response with high probability of prediction of the consumer reaction (Kapsalis and Moskowitz, 1977).

Unfortunately, correlations between objective and sensory methods of texture represent a very controversial subject that has frustrated many researchers. (Szczesniak, 1968) and conflicting as well as discouraging results have been reported in regard to the degree of their correlation (Szczesniak, 1968). Excellent reviews relating to work done in this area have been published by Kapsalis et al. (1973), Kapsalis and Moskowitz (1978), Moskowitz and Kapsalis (1976), Kapsalis and Moskowitz (1979), Moskowitz (1981), Moskowitz and Jacob (1987) and Szczesniak (1987).

## 2.4.1 Methods of Expressing Relationships

Sensory and psychorheological models are important in texture studies. While sensory models, in general, imply a stimulus-organism-response design, psychorheological models consists of a mathematical expression relating sensory rheological data to the corresponding mechanical data, these two sets of data usually being considered as output and input, respectively (Drake, 1979).

Associations between subjective and objective texture measurements may be expressed in graphical or mathematical/statistical terms. In a study of a possible relationship between two types of variables, a plot of an x-y co-ordinate system is usually the first step; clues on linearity, necessity of fitting a curve of higher order, patternless scatter, or even some fault in the correction of the experimental data may be gained by an inspection of this plot (Kapsalis et al., 1973).

The presence of linearity greatly simplifies the study of a relationship and the making of possible predictions. Because of this advantage, even if linearity is not at first evident, transformations of data are often used to achieve a linear relationship. Such transformations may involve (a) expression of the instrumental data in different physical form (use of work instead of compressive force) or mathematical form (logarithmic conversions). Almost any curve can approximate a straight line when sufficiently short intervals are considered; however, such an approximation may obliterate important differences which need to be investigated (Kapsalis et al., 1973).

2.4.1.1 Correlation Analysis: In correlation analysis the basic question is whether or not two variables move together. There is no assumption of casuality. In fact, it may be that changes in the two variables may be the result of third variable which may be unspecified (Kapsalis et al., 1973).

Various correlation coefficients quantify the relation between two variables. The Pearson correlation coefficient (r) is most widely used. It applies to data which possess atleast interval-level scale properties (Moskowitz, 1981).

Correlation analysis using multiple correlation (between one variable and a combination of other variables) becomes useful when dealing with a sensory perception determined from many instrumental measures. It has one major drawback - it indicates which combination of variables are correlated with sensory attribute, but does not inform us about the basic relation between the combination of instrumental and the sensory perception. Questions such as Is the relation additive? Multiplicative? are not answered by it (Moskowitz, 1981).

2.4.1.2 Regression Analysis: Beyond developing a measure of relatedness of two variables, one can ascertain the relation itself using regression analysis. It has implicit in it the assumption of a unilateral casuality (Kapsalis *et al.*, 1973).

Regression analysis allows the experimenter to (a) select a mathematical equation which is assumed to relate the two variables, and (b) by a statistical analysis, estimate the parameters of that equation (Moskowitz, 1981).

Often simple linear equations such as the one given below adequately describe the sensory-instrumental relation (Moskowitz, 1981):

$$S = Ko + K_1X_1 + K_2X_2 \; . \; . \; . \; . \; . \; K_nX_n \qquad (1)$$

where,

$S$ = sensory response,

$\left.\begin{matrix} X_1 \\ X_n \end{matrix}\right\}$ = intensity of physical variables.

In other instances better fitting equations are developed with a non-linear combination of physical variables. Some of the possible combinations are shown below:

$$S = K_o + K_1X_1 + K_2X_2 + K_3X_1X_2 + K_4X_1^2 + K_5X_2^2 \;.........(2)$$

$$S = K_o + K_1X_1 + K_2X_2 + K_3 \; (X_1/X_2) \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; (3)$$

$$S = K_o \; (e^{K_1X_1} + e^{K_2X_2} \;.......e^{KnXn}) \;................ \; (4)$$

The full quadratic equation (equation-2) is less parsimonious than a simple linear equation. Nonetheless, the full quadratic equation permits non-linearities, and permits one to model some interactions among the physical variables (Moskowitz, 1981).

It is debatable where one should choose the linear equation, settling for parsimony, or the quadratic function, searching for an enhanced goodness-of-fit. Linear equations allow one to understand at a glance, relations between sensory and instrumental variables. They do not model interactions. Quadratic equations are more complicated-one does not obtain as clear an idea of the interrelations, since the surface is curved. On the otherhand, one can be sure of a betterfit to the date, since there are a greater number of free parameters in the equation (Moskowitz, 1981).

The logarithmic function is often used to relate physical intensity to subjective magnitude. The equation is written:

$$S = K \log (I) + c \quad \text{.......................} \quad (5)$$

where, S = subjective magnitude, I = physical intensity. In semi-log co-ordinates the function becomes a straight line if the sensory rating is plotted as a function of the logarithm of physical intensity. The logarithmic function often appears when the panelist rates sensory intensity using a category scale. The equation-5 means that a ten fold increase in physical intensity (I) produces a k unit addition increase in the sensory rating (Moskowitz, 1981).

Stevens (1953, 1975), while studying sensory-instrumental correlations, found that power functions may relate sensory responses to physical intensities, when panelists assign ratings which possess ratio scale properties. The power function can be expressed as:

$$S = K I^n \text{ ..................................(6)}$$

where, S = sensory intensity, I = physical measured intensity and k and n are parameters computed from the data (Kapsalis and Moskowitz, 1979). The power function becomes a straight line after a simple transformation:

$$\log S = n \log I + \log k \text{ ....................(7)}$$

Moskowitz (1981) suggested multi-step approach to inter-relating hedonic performance judgement and instrumental measures involving following 3 steps:

1) Develop linear or power equations which relate sensory to instrumental measures.

2) Develop quadratic equations relating performance ratings.

3) Develop a combined equation.

As indicated by Moskowitz (1981), subjective-objective interactions for the food industry suggests a multi-stage process:

1) select the appropriate subjective attribute
2) select the instrument measure or set of measures that produce sensory perception
3) Hypothesize candidate equations relating subjective and instrumental variables.
4) Estimate the parameters of that equation by least-squares procedures.
5) Estimate the goodness-of-fit the function to the actual data, by means of correlations and f ratios.

## 2.5 TEXTURE OF DAIRY PRODUCTS

Although the flavour of dairy products has concerned researchers for many yaars, their textural properties have received relatively little attention. The dairy industry has traditionally considered the texture of a product in terms of its structural appearance rather than in terms of its sensory properties perceived during mastication (Cooper, 1987).

Among dairy products, milk and cream fall in liquids. Fermented milk products such as yoghurt display slightly more complex textural properties. Butter display properties of a plastic solid. Cheese has the most complex structure of all dairy products; there are as many variations in its structure as there are varieties. Products such as caseinates and whey proteins show relatively simple textural properties in solution. However, when these proteins are used as functional ingredients in more complex food systems, their binding, gelling and whipping properties have a major influence on the texture of the final product (Cooper, 1987).

The published literature on rheology of heat-and-acid coagulated Indian dairy products is very scanty. Such products seem to resemble certain varieties of cheese, hence to give an idea of textural characteristics of cheese pertinent literature has been reviewed here.

2.5.1 Texture of Cheese

One of the earliest attempts to relate textural parameters of cheese, as judged by a panel, to rheological properties was made by Davis (1937). The work was considered basis for defining quality of foods with rheological concepts (Mohsenin, 1970).

While most cheeses are rheologically classified as visco-elastic compounds (Sherman, 1976) certain varieties are plasto-elastic products (White, 1970), the former being capable of demonstrating both elastic and viscous behaviour and the latter plastic and elastic behaviour. Cheese is primarily composed to aggregates of water, fat and protein, in approximately equal proportions. The protein component (i.e. casein) is responsible for the solid form of mature cheese due to its network structure (Shama and Sherman, 1973b). During cheese making casein micelles are first changed to filaments with a granular structure through the action of rennet and then to a fibrous net work later on (Prentice, 1972). Variations in processing or storage conditions affect the physical properties of the cheese which ultimately affects the textural characteristics.

Textural characteristics which are evaluated in cheeses are hardness, springiness, smoothness, crumbliness, firmness, stickiness, sliceability and spreadability (Davis, 1937; Thomas et al., 1970). The New Zealand Dairy Research Institute has established a variety of terms to evaluate cheddar cheese, including rubberiness, crumbliness, smoothness, stickiness and residual mouthfeel which would correlate to TPA terms, springiness, cohesiveness, gumminess and adhesiveness, respectively. Lee et al. (1978) evaluated TPA parameters of selected cheeses, including mozzarella, old cheddar, process and colby. This study affirmed that hardness (firmness) was the most-important parameter with respect to consumer preference and therefore, necessitates appropriately correlated instrumental analysis.

Chen et al. (1979) used a constant speed plunger, with a diameter of 0.64 cm, to evaluate six textural characteristics, namely, hardness, cohesiveness, adhesiveness, elasticity, gumminess and chewiness of a wide range of cheeses. These parameters were found to correlate well with both sensory scores and with composition and pH. Further analysis suggested that the protein content was the variable most responsible for textural changes observed, followed by salt, water, pH and fat. Green et al. (1985) employed compression and penetration tests with cheddar cheese in an attempt to correlate these measurements to sensory ratings, but found that sensory analysis did not relate well with any instrumental method, possibly because the way in which sample fractured was different when assessed by sensory panels and by compression tests.

Shinin (1987) undertook a study to determine the appropriateness of various rheological analyses of six varieties of cheese including cheddar cheese. His results from compression analysis suggest that hardness evaluations may not be appropriate for all cheeses. This is because the harder cheeses fracture at lower levels of compression, compared to softer cheeses. As a result estimating the force at a level of deformation greater than deformation of fracture would lessen the hardness value.

## 2.6 TEXTURE OF HEAT AND ACID COAGULATED INDIAN MILK PRODUCTS

Chhana and paneer are the major heat-and-acid coagulated indigenous milk products.

Chhana and paneer represent a semi-solid product obtained by coagulation of boiled whole milk (while still hot) and subsequent draining of whey. Paneer-making requires pressing of the coagulum, whereas in chhana the whey drains by itself. Thus structurally they are somewhat similar to certain fresh (soft) cheeses. Yet the distinctly different conditions of coagulation and removal of whey during preparation of chhana/paneer as compared to most cheeses imparts typical texture to these products. Although no systematic attempts have been made to characterize the texture of chhana/paneer either by sensory or instrumental methods, conditions of production have been found to be most important in relation to texture of these products. Based on this, various aspects of manufacture of chhana and paneer have been investigated in order to obtain a desirable quality product, which otherwise, has been restricted to cottage production on very small scale and little is known about the desirable textural characteristics.

### 2.6.1 Texture of Chhana

Texture of chhana is very important with regard to its application in the preparation of various sweets. Chhana of fine texture with velvety body is considered desirable (Warner, 1951 and Ray and De, 1953). A compact, close-knit smooth texture (Rangappa and Achaya, 1973), and a soft body are believed to ensure manufacture of good quality Rasogolla, but a slightly less soft body together with smooth texture is desirable for making good quality Sandesh (Ray and De, 1953).

Most of the information in the literature on the textural assessment of chhana pertains to its sensory properties of the product. In general, texture of chhana of varying quality has been described using arbitrary terms such as moist, creamy and greasy for visual attributes; scale terms soggy, soft, velvety hard for body characteristics, and smooth, fine, coarse and granular for texture (Davis, 1940; Ray and De, 1953; De and Ray, 1954; Kundu and De, 1972; Rangappa and Achaya, 1973; Singh and Ray, 1977a; Iyer, 1978; Gera, 1978; Ahmad et al., 1980; Soni et al., 1980; Bhattacharya and Desraj, 1980a,b; Kumar and Srinivasan, 1982; Sen and De, 1984; Sen, 1986)

The texture of chhana has been reported to be influenced by factors such as type of milk, its fat level and conditions of coagulation such as pH, time and temperature of coagulation and type and strength of the acidulant (De, 1980). The basic method for manufacture of good quality chhana from cow milk as standardized by De and Ray (1954) involves: heating milk to boil, coagulation with 1-2% acidulant solution at about 82$^{o}$C within 30 to 60 sec. by reducing the pH to around 5.4, immediate straining of whey and hanging the mass till the dripping of whey ceases. Further, they stated that lactic acid produced a granular texture which was desirable for Rasogolla making, whereas citric acid produced pasty chhana desirable for Sandesh making. Adopting above technique for buffalo milk, they observed that the resultant chhana was slightly hard, greasy, and coarse which was not suitable for subsequent use. Hence, buffalo milk was reported to be unsuitable for chhana-making. (De and Ray, 1954).

Several attempts have been made to improve the texture of buffalo milk chhana (Kundu and De, 1972; Soni, 1978 and Iyer, 1978) and also to elucidate the causes for its poor texture (Ganguli, 1974).

Date et al. (1958) treated buffalo milk with a mixture of sodium dihydrogen (9g) and monohydrogen phosphate (7g) or 0.1-0.2% sodium citrate and observed that both treatments resulted in soft chhana which was suitable for preparation of Rasogolla. They noted that hard texture of buffalo milk chhana was due to its high calcium content. According to Jagtiani et al. (1960) addition of 0.2-0.3% sodium citrate as a softening agent and storing the hot buffalo milk for sometime before effecting coagulation, helped in producing a soft chhana. They further demonstrated that as the amount of calcium added to cow milk increased, the resulting Rasogolla was harder.

In another process modification Kundu and De (1972) proposed homogenization of buffalo milk standardized to 5% fat before boiling and coagulating at 70$^{o}$C employing 1% citric acid at pH 5.7.

The conditions of coagulation were studied by Iyer (1978) who suggested that good quality chhana could be obtained by coagulating cow milk at 70$^{o}$C (pH 5.1) using 2% citric acid. He further observed that treatment of buffalo milk with 0.05% sodium citrate before boiling, dilution with 25% or 50% water and coagulation with 1% citric acid solution improved softness and cohesiveness of chhana. However, addition of 40% or 60% cow skim milk, acidification of milk prior to coagulation, ten minutes delayed straining and homogenization were observed to have adverse effects on texture of chhana made from buffalo milk. Kumar and Srinivasan (1982) reported that desirable quality chhana could be produced from buffalo milk by adopting conditions of coagulation and method of delayed straining as suggested by Kundu and De (1972), but excluding the homogenization step.

Soni (1978) observed that in addition to a combination of 70°C temperature and pH 5.7 for coagulation, delayed straining (by holding the coagulated mass in whey for about 30 min) yielded chhana with desirably soft and smooth texture.

Even in cow milk, the production parameters can be of considerable importance with respect to texture of chhana. Singh and Ray (1977a) studied the effect of coagulants on texture of cow milk chhana and noticed that citric acid coagulation (pH, 5.77) produced chhana with soft and smooth texture, whereas lactic acid and sour whey produced chhana with hard and granular texture.

Bhattacharya and Desraj (1980a) suggested the use of 0.8% citric acid, cooling the boiled cow milk to 80-90°C prior to coagulation, holding coagulated mass in whey for 5-10 min and cooling chhana mass in tap water for 20 to 30 min so as to obtain slightly firm, elastic and smooth textured chhana which was considered suitable for Rasogolla making. Cooling the boiled cow milk to 80°C prior to coagulation (with 2% lactic acid) at pH 5.5 to 5.6 was successfully employed to yield desirable body and texture of chhana from cow milk by Kumar and Srinivasan (1982).

Chhana of desirable body and textural attributes, suitable for Sandesh-making by employing calcium lactate as coagulant has been obtained by Sen and De (1984). The strength of calcium lactate (4%), pH of coagulation

(5.85) and temperature of coagulation (85°C) were found to be optimum in this regard (Sen, 1985; Sen and Rajorhia, 1986[a] and Sen, 1986).

Chhana suitable for preparation of Sandesh was obtained from goat milk by Jailkhani and De (1980) employing the method as suggested by De and Ray (1954). Moorthy and Rao (1982) prepared chhana suitable for Rasogolla making from goat milk with 0.25% of citric acid as coagulant.

Gera (1978) studied rheological properties of cow, buffalo and skim milk chhana by adopting physical tests which included pitching number, penetration value, viscosity, springiness and density of chhana. Springiness was determined by an instrument developed for this purpose by Gera and Rajorhia (1979), who found that buffalo milk chhana was most springy followed by mixed milk (1:1) and cow milk chhana. Gera (1978) further observed that the type of coagulant caused minor variation in the compactness of chhana and that citric acid gave higher viscosity. Lower pH of coagulation (4.6) increased the hardness and viscosity of chhana; maximum springiness was observed at pH 5.7 for mixed and buffalo milk chhana, but at pH 5.1 for cow milk. Density of chhana was maximum at pH 4.6. Temperature of coagulation affected the softness and springiness of chhana. Higher viscosity of chhana was evident at higher temperature of coagulation, while density of chhana remained unaffected.

### 2.6.2 Texture of Paneer

2.6.2.1 Raw Paneer: Suitability of paneer for preparing various culinary dishes is greatly influenced by its texture. Desirably, paneer should have optimum firmness (neither too firm nor too hard) so that it permits easy cutting and slicing and yet is tender enough not to resist crushing during mastication. It should also be compact, smooth and velvety in nature (Patil and Gupta, 1986). Terms like hard, soft, pasty, crumbly, rubbery, chewy, mealy, meaty, coarse, open etc. have been used in relation to paneer texture (Arora and Gupta, 1980; Chawla, 1981; Patil and Gupta, 1986 and Sachdeva and Singh, 1988). Thus, as observed for chhana, only sensory terms are prevalent in literature pertaining to the texture of paneer and no information on the sensory textural quality as related to objective textural aspects of paneer is available.

Paneer is manufactured in a similar way except that the coagulated mass is pressed and then cooled in chilled water (4-6$^{o}$C for 2-2.5 hr) to obtain a firm block of paneer. It is evident from literature, in contrast with chhana, that buffalo milk has predominantly been used for paneer making (Bhattacharya et al., 1971; Arora, 1979; Chawla, 1981; Sachdeva et al., 1985, and Singh et al., 1984). Paneer from cow milk tends to be soft, weak and fragile as against firm, cohesive and spongy obtained from buffalo milk (Arora and Gupta, 1980 and Singh et al., 1984).

Bhattacharya *et al.* (1971) standardized the procedure for the manufacture of paneer on a pilot scale: buffalo milk standardized to 6% fat was heated to 82°C for 5 min and then cooled to 70°C. Hot (70°C) 1% citric acid solution was added slowly to effect coagulation. The coagulum was allowed to settle for 5 min taking care that temperature did not get below 63°C. The curd was then hooped (35 x 28 x 10 cm) and pressed (45 kg for 15 min). The pressed paneer was cut into 6-8 equal sized pieces and immersed in chilled water (4-6°C) for 2-3 hr. The chilled paneer was then allowed to stand for 15-20 min on a wooden plank so as to facilitate the drainage of water. The paneer so prepared was found to have desirable textural properties.

Paneer prepared using above technique from 4%, 5% and 6% fat buffalo milk had different hardness values (penetration values) as reported by Arora and Gupta (1980). Rao *et al.* (1984) obtained desirable body and texture in paneer, made from 6% fat buffalo milk, heated to 85°C and coagulated by 0.3% citric acid by weight of milk.

In an attempt to develop a low fat paneer, Chawla (1981) modified the technique of Bhattacharya *et al.* (1971) with respect to final heating (85°C, 10 min) and pressing time (10 min). He observed that fat content in paneer contributed to its soft and spongy texture. He claimed that fairly acceptable quality paneer could be prepared from 3% fat buffalo milk, however, paneer prepared from 1.5% fat buffalo milk was hard, rubbery and chewy.

Sachdeva and Singh (1988) optimised the processing parameters of paneer manufacture which involved: standardization of buffalo milk to a fat:SNF ratio of 1:1.65, heating to 90°C without holding, coagulating the milk at a pH between 5.30-5.35 using 1% citric acid solution. The resultant paneer had desirable textural attributes. In another process, 0.15% pregelatinized potato starch or 0.10% sodium alginate was added to milk so that coagulation could be effected at 90°C so as to eliminate cooling of milk from its final heating temperature to coagulation temperature (70°C) (Sachdeva, 1983). The resulting product had normal texture; there was no hardening effect as was observed in the absence of any hydrocolloid. Sachdeva and Singh (1987) while studying effect of different non-conventional coagulants (namely hydrochloric, phosphoric, and tartaric acids, acidophillus or sour whey etc.) in the manufacture of paneer concluded that hydrochloric or phosphoric acid could be used in the manufacture of paneer without loss of its quality.

Shukla et al. (1984) studied the effect of different acidulants on textural characteristics of paneer prepared from mixed milk (cow and buffalo). Use of citric acid gave a product with greatest hardness while hydrochloric acid gave the lowest hardness. Paneer made by citric + tartaric acid seemed to have more gumminess and chewiness. Least chewiness was observed in paneer made by using lactic acid. Shukla *et al.* (1988b) reported that acidulants such as citric, tartaric, citric + hydrochloric and tartaric + hydrochloric acids resulted in paneer with better body and texture of paneer samples as compared to paneer prepared using 0.1 N hydrochloric, lactic or citric + lactic acids.

Singh and Kanawjia (1988) observed that good quality paneer could be obtained using a combination of 0.5% calcium lactate and 80°C as the temperature of coagulation.

Sachdeva *et al.* (1985) suggested addition of 1g calcium chloride per litre of milk and coagulation at final heating temperature (90°C) to prepare satisfactory quality paneer from cow milk. Vishweshwariah and Anantakrishnan (1986) produced desirable quality paneer from cow milk by coagulation at 80°C with 2% citric acid solution. Acceptable quality paneer from cow milk was also produced by Shukla *et al.* (1988a) using 1% citric acid.

Kalab *et al.* (1988) studied the microstructure of paneer and showed that the product had a granular structure consisting of protein particles having a core-and-lining ultrastructure.

2.6.2.2 Fried and Cooked Paneer: Generally raw paneer is deep-fat fried before being cooked alongwith vegetables. These processes of frying and cooking are believed to influence the body and textural characteristics of raw paneer. Many researchers (Arora and Gupta, 1980; Chawla et al., 1985; Sachdeva and Singh, 1987, and Sachdeva and Singh, 1988) have evaluated effect of frying and cooking on body and texture of raw paneer. However, these observations were based solely on sensory evaluation.

Bhattacharya et al. (1971) employed deep fat frying of paneer in hydrogenated fat and evaluated compositional changes upon frying. They observed about 15% reduction in moisture, an increase in fat content of paneer made from low fat milk and a decrease in fat content of paneer made from high fat milk; the total nitrogen content in fried paneer was found to be more than that in the corresponding fresh paneer, the increase being due to reduction in the moisture content.

Arora and Gupta (1980) fried paneer (prepared from 4, 5 and 6% fat buffalo milk) in vegetable oil and noted that the body and textural differences observed in raw paneer narrowed down upon frying, all fried paneer samples being equally acceptable.

Chawla et al. (1985) evaluated paneer in raw, fried and fried and cooked forms. They noted that frying and cooking tended to narrow down the body and textural differences of raw paneer made from buffalo milk with various fat levels (6.0, 5.5, 5.0, 4.5, 3.0, 1.5 and 0.05% fat). However, 1.5% fat content resulted in a paneer of unacceptable body and texture even after frying and cooking as it was hard, rubbery and chewy. Homogenized milk paneer did not show improvement in body and texture even when fried and cooked.

Sachdeva and Singh (1988) reiterated the findings of Chawla _et al_. (1985). Further, they noticed that the effect of lower temperature of coagulation (60°C) on body and texture of raw paneer was also seen in the fried and cooked paneer; such paneer lost its size and shape upon frying and cooking.

Kalab _et al_. (1988) noted that deep frying (175°C, 4-5 min) of paneer led to compaction of the paneer structure and also the individual protein particles, whereas cooking of the fried paneer by boiling in 1.5% salt water for 5 min resulted in partial restoration of the overall structure of paneer and the ultrastructure of the protein particles.

## 2.7 TEXTURE OF CHHANA-BASED SWEETS

Chhana has largely been used as a base and filler for the production of a large variety of sweets such as Rasogolla, Sandesh, Ras-malai, Pantooah, chhana-murki etc., amongst which the first two are the most popular. The textural attributes of chhana based sweets depend mainly on the texture of chhana besides their preparation technique. However, very limited information is available on textural aspects of these products.

### 2.7.1 Texture of Rasogolla

Rasogolla normally has round shape, smooth body and spongy texture, which are dependent on texture of chhana, composition of chhana-dough, concentration of sugar-syrup, and time and temperature of cooking (Soni et al., 1980). Based on the quality of Rasogolla available in Calcutta market Mitra et al. (1967) divided them into two types viz. ordinary and sponge Rasogolla. The chemical composition of Rasogolla varied between the varieties (Mitra et al., 1967) and is greatly influenced by factors affecting its texture (Soni et al., 1980). Rasogolla manufactured from cow milk chhana has been observed to have the desired smooth body and spongy texture. But Rasogolla from buffalo milk lacks sponginess.

Preparation of Rasogolla in the laboratory under controlled conditions has been outlined by many workers (Date et al., 1958; Anantakrishnan and Srinivasan, 1964; De, 1976; Singh and Ray, 1977b; Bhattacharya and Desraj, 1980a,b; and Soni et al., 1980). The essential steps in the manufacture of Rasogolla are: preparation of soft, smooth chhana; addition of optional ingredients like semolina, maida, wheat flour, baking powder, samundar jhaag etc. if desired; kneading of the mixture to obtain a soft and smooth dough; preparation of balls; cooking balls in sugar-syrup, and dipping the Rasogolla in hot sugar-syrup.

Soft and smooth chhana is the basic requirement for obtaining soft and spongy Rasogolla. The modifications suggested a relation to chhana making technique have been discussed earlier (vide 2.6.1).

Singh and Ray (1977b) suggested use of lactic acid to obtain chhana for Rasogolla making from cow milk. Bhattacharya and Desraj (1980a,b) extensively studied the production of Rasogolla from cow milk and also developed a pressure-cooker method for Rasogolla manufacture. They suggested coagulation pH of 5.4 and a temperature of 80°C for obtaining chhana from 4% fat milk so that chhana containing 55 to 58% moisture would yield soft, spongy Rasogolla. At lower pH of coagulation Rasogolla were hard and texture-wise irregular. Higher fat in chhana improved the body and texture of Rasogolla, whereas lesser fat resulted in hard body and grainy texture in Rasogolla. Rasogolla obtained from chhana with less than 50% moisture lacked sponginess, softness and was grainy, whereas above 60% moisture in chhana, resulted in Rasogolla which was soft but could not retain its round shape.

A sugar syrup of varying strength (ranging from 40 to 80%) has been used for cooking Rasogolla (Date _et al_., 1958; Anantakrishnan and Srinivasan, 1964; Jagtiani _et al_., 1960; Singh and Ray, 1977b; Bhattacharya and Desraj, 1980a,b; and Soni _et al_., 1980). Bhattacharya and Desraj (1980a,b) found that sugar concentrations in the range of 40 to 60% were satisfactory to retain the shape as well body and texture characteristics of Rasogolla. However, 55% was considered optimum.

Tarafdar et al. (1988) employed cooking of chhana balls in boiling water and subsequently dipped them in sugar syrup. They reported very slight improvement in the overall sensory score of Rasogolla made by mechanical kneading as compared to manual kneading.

2.7.2 Texture of Sandesh

Sandesh is one of the oldest and most popular chhana-based sweet of Eastern India and Bangladesh. Many varieties of Sandesh are sold in the market. Each type differs in its appearance, composition, flavour and texture (Sen and Rajorhia, 1985). Sandesh can be grouped into three main classes; soft grade (Narampak), hard grade (Kharapak) and Kacchagolla. Soft grade Sandesh has a characteristic soft cohesive body and smooth texture with small size grains, whereas hard grade has a firm, crumbly, cohesive body, coarse, gritty and chewy texture and big size grains. Kacchagulla has a mixed characteristic of these two types; it has a soft weak body lacking cohesiveness but very coarse and granular texture (Sen and Rajorhia, 1987).

As for Rasogolla, cow milk chhana is preferred for Sandesh preparation too. The method of Sandesh preparation varies from shop to shop and from variety to variety. In general, thoroughly kneaded chhana is admixed with sugar (preferably ground) in a open metal pan by continuous stirring with the help of flat-edged wooden/ stainless steel ladle while heating the mixture on a very slow fire. Heating is continued (at 75-85°C) for 15-25 min to the desired consistency.

Singh and Ray (1977b) observed that for Sandesh making citric acid chhana was better than lactic acid chhana. Recently the use of calcium lactate as coagulant for making chhana intended for Sandesh preparation has been advocated (Sen and De, 1984; Sen, 1985; 1986, and Sen and Rajorhia, 1985, 1986a,b).

## Conclusion

It is thus evident that basic aspect of foods texture-an important fundamental sensory property has been extensively studied in relation to objective (instrumental) measurement, sensory evaluation and the interrelationships, as well as effect of composition on the texture. Among dairy products, various cheeses, particularly semi-hard varieties, have received maximum attention of investigators. A large number of instrumental methods have been developed alongwith generally accepted texture terminology. Attempts, though not wholly successful, have also been made to develop correlations between objective textural data and sensory information. However, no such attempts have been made in relation to Indian indigenous milk products, in spite of reasonably standardized technology for their production. Thus in absence of adequate information about the desirable attributes of product's texture particularly in terms of objective parameters, such of the research concerning processing aspects has largely depended on consumer response through market feedback.

# MATERIALS

# AND

# METHODS

# 3. MATERIALS AND METHODS

This chapter deals with the materials employed and experimental procedures used during the investigation. The necessary information has been dealt with under following groups:

a) Collection of market samples
b) Preparation of laboratory samples
c) Chemical analyses
d) Objective texture assessment
e) Sensory texture assessment
f) Statistical analyses

## 3.1 COLLECTION OF MARKET SAMPLES

A preliminary survey was conducted to select suitable markets and shops for collection of market samples of chhana, paneer, Rasogolla and Sandesh, keeping in view the quality of product sold, scale of handling and popularity of the vendor. Accordingly Delhi market was selected for chhana, Rasogolla and Sandesh, whereas paneer samples were collected from Karnal market.

### 3.1.1 Chhana

Samples were obtained from six prominent shops located in Karol Baugh area of Delhi. At the request of vendors code numbers have been used to designate different samples. About 750 g of fresh chhana was purchased and carried in stainless steel containers (16 cm dia., 5 cm h) with tightly closing lids. These containers were kept in a plastic ice-box (35 x 20 x 16 cm, 'Brite' Bright Bros., Bombay). After about 6 hr spent in transit, the samples were transferred to a BOD incubator (Akash Deep, Delhi) maintained at 15°C and held overnight before subjecting them to chemical analyses, and objective and sensory texture evaluation.

3.1.2 Rasogolla

Rasogolla of three varieties, viz. small (SL), normal (NL) and sponge (SG) were purchased from two popular vendors of Delhi. About 24 pieces of each variety were collected in stainless steel containers (vide 3.1.1). These samples were transported and tempered as in the case of chhana (vide 3.1.1.).

3.1.3 Sandesh

Eight samples of Sandesh (pieces each) were procured from different vendors in Delhi (Chittranjan Park, Chandni Chowk and Bengali markets) and were transported and tempered as above (vide 3.1.1).

3.1.4 Paneer

About 750 g of fresh paneer was obtained from each of the six popular vendors in Karnal market. Samples were collected in stainless steel containers (vide 3.1.1), transferred after about an hour to the tempering cabinet at 15°C and held overnight before being subjected to various analyses.

## 3.2 PREPARATION OF LABORATORY SAMPLES

Details of the preparation of laboratory samples of chhana and paneer are given below.

### 3.2.1 Materials

3.2.1.1 Milk: Pooled cow and buffalo milks were obtained from the Experimental Dairy of the Institute. All raw milk was farm produced and about 4 to 5 hr old when used. pH ranged from 6.6 to 6.7 for cow milk and from 6.7 to 6.8 for buffalo milk. The ranges of fat and total solids were 4.0 to 4.5% and 12.7 to 13.4% for cow milk, and 6.6 to 7.7% and 16.5 to 17.5% for buffalo milk, respectively.

3.2.1.2 Coagulants: Lactic acid, IP (E.Merck, India), citric acid, IP/BP (Sarabhai M. Chemicals, SMC, Baroda) and calcium lactate, IP (Shalg Pharmaceuticals, Bombay) were used as coagulants, in desired concentrations.

3.2.1.3 Other additives: Sodium citrate, IP/BP (Sarabhai, Baroda), sodium alginate (Chemical De Centre, New Delhi) and calcium chloride (fused), LR (Glaxo Laboratories, Bombay) were used.

3.2.1.4 Vegetable Oil and Common Salt: Hydrogenated vegetable fat ("Dalda" vanaspati, Lipton India Ltd., Calcutta) was used for frying of paneer. Common salt (Tata Chemicals, Bombay) was employed as 2.25% solution for cooking the fried paneer.

### 3.2.2 Processing Conditions

3.2.2.1 Standardization: Cow and buffalo milks were standardized to the desired fat level by adding respective skim milk or cream as the case may be. Mechanical cream separator ("Kamdhenu", Sinhal Metal Industries, Bombay; capacity 550 lit milk/hr) was used for separation of milk.

3.2.2.2 Homogenization: Whenever required, milk was homogenized at 60-65$^{o}$C and 176 kg/cm$^{2}$ pressure using a Gaulin (USA) homogenizer.

3.2.2.3 Heating of Milk: Milk taken in a stainless steel (SS) containers (capacity, 7 l) was heated to the desired temperature using a boiling water-bath.

3.2.2.4 Cooling of Milk: Milk was cooled to the desired temperature using tap water.

3.2.2.5 Coagulation: Coagulation of milk was effected within 60 sec by the addition of coagulant solution of the required strength and stirring the content continuously. The coagulum-whey mixture was held for required time before removing the whey by straining through a muslin cloth.

3.2.2.6 Pressing: For paneer making, the coagulated mass held in the muslin cloth was transferred to a wooden hoop (16x7.5x6 cm) the cloth serving as lining, and the curd was pressed under a dead weight of 6 kg for 15-20 min.

3.2.2.7 Cooling of chhana/paneer: Chhana was cooled by dipping in pasteurized tap water (25-30°C), whereas paneer, after pressing was kept in pasteurized chilled water (4-6°C) for 2-3 hr to effect cooling.

### 3.2.3 Specific Procedures

Approximately 4-5 kg lots of cow, buffalo or mixed milks (standardized, if required) were used for the preparation of chhana or paneer according to procedures outlined in Fig. 3.1 to 3.3 (chhana) and Fig. 3.4 and 3.5 (paneer). All the chhana and paneer samples were packaged in the polyethylene bags (capacity, 1 kg) and tempered overnight in a BOD incubator at 15°C before subjecting them to chemical, sensory and objective textural analyses.

### 3.2.4 Frying and Cooking of Paneer

Raw paneer was cut into pieces of equal size (1.9 cm dia. and 2.0 cm height) and fried in "Dalda" vanaspati (hydrogenated fat) heated to a temperature of 175-185°C using an SS open pan on an electric heater. The frying time was 5 to 7 min for 18 to 20 pieces taken at a time. The paneer pieces were frequently turned during frying using a perforated SS ladle.

Fried paneer pieces were boiled for 5 min in twice its weight of 2.25% salt water. Paneer so cooked was allowed to cool to ambient temperature before transferring for overnight tempering at 15°C.

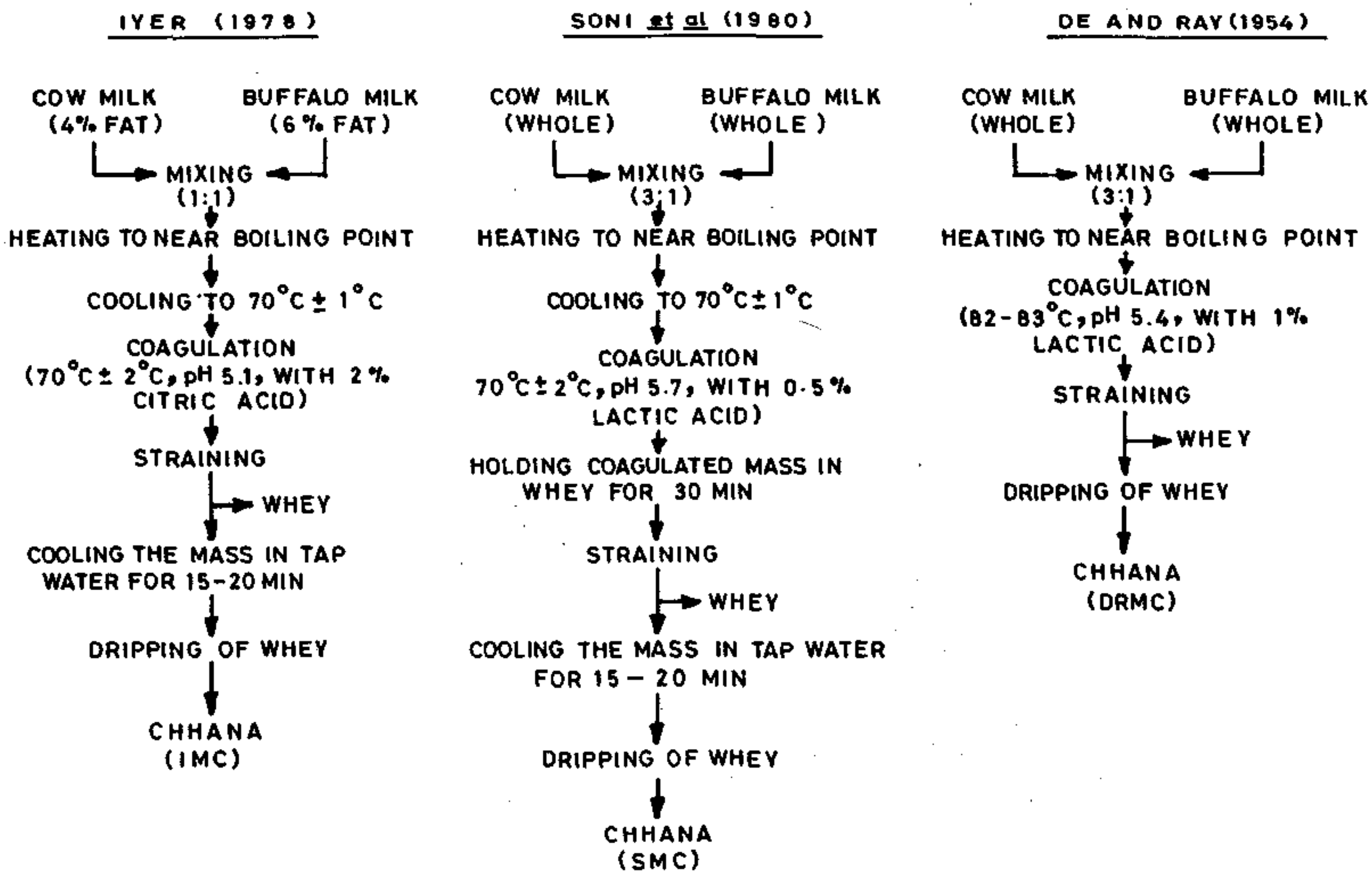


FIG.3.3 METHODS USED FOR MAKING CHHANA FROM MIXED MILK

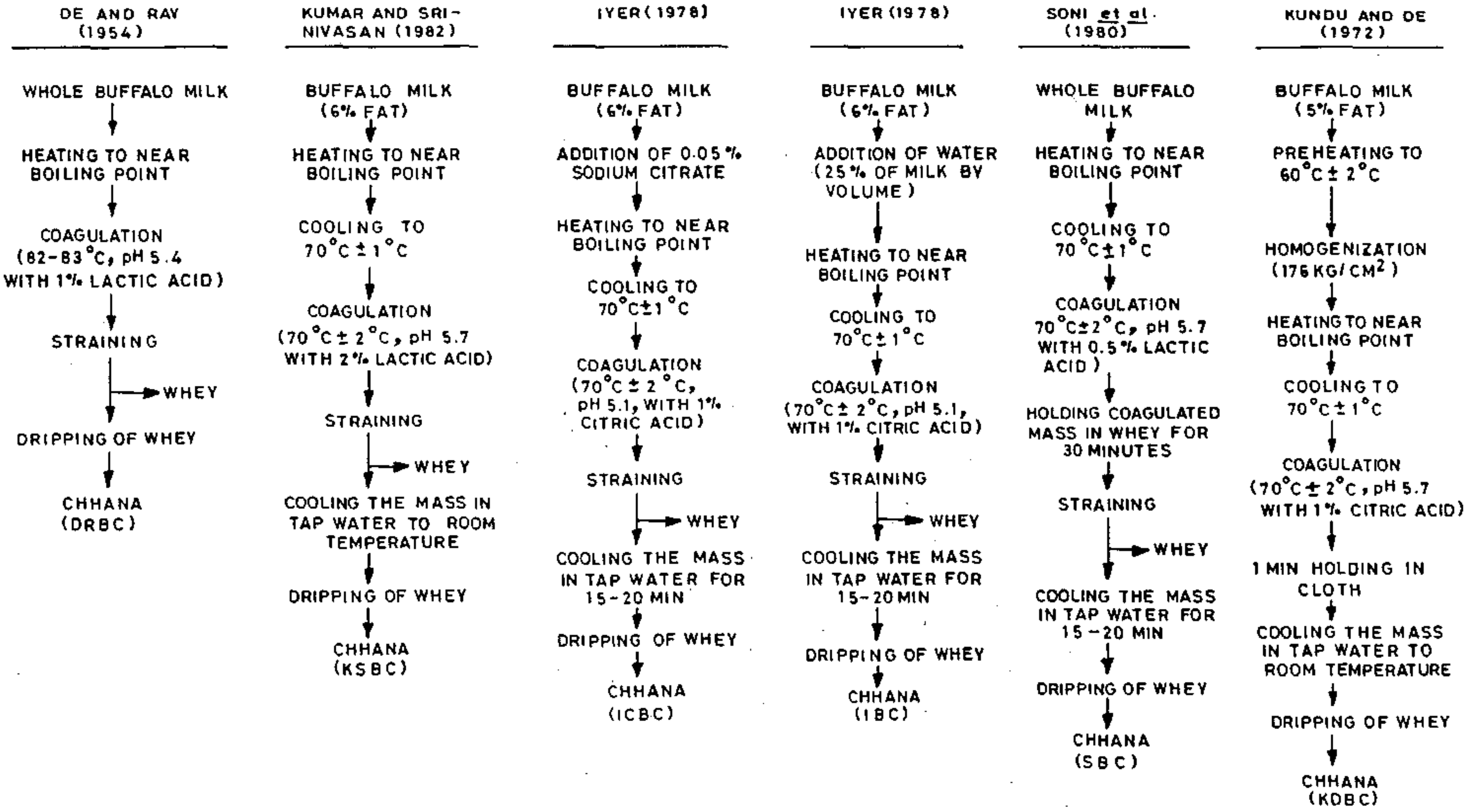


FIG. 3.2 METHODS USED FOR MAKING CHHANA FROM BUFFALO MILK

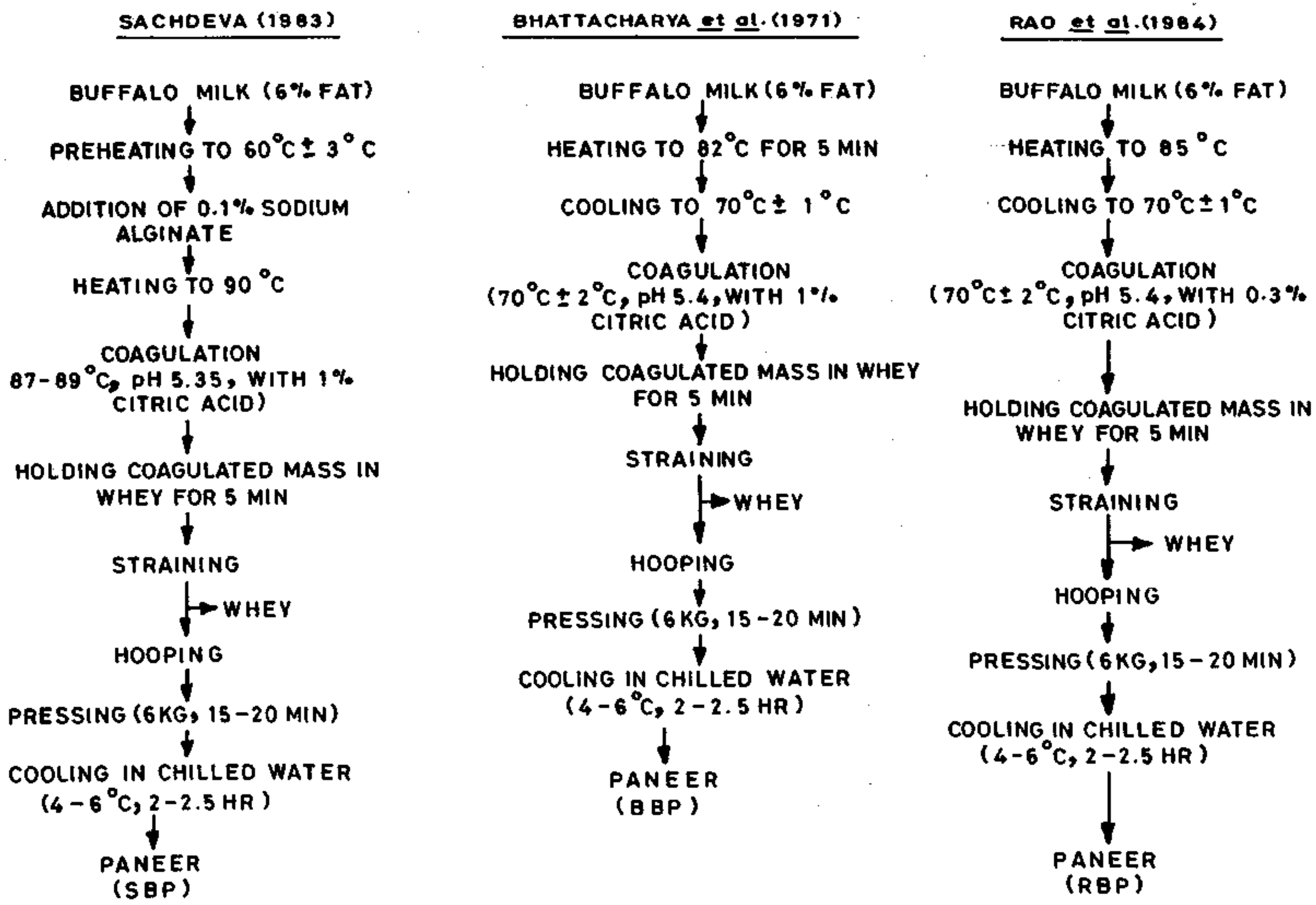


FIG. 3.4 METHODS USED FOR MAKING PANEER FROM BUFFALO MILK

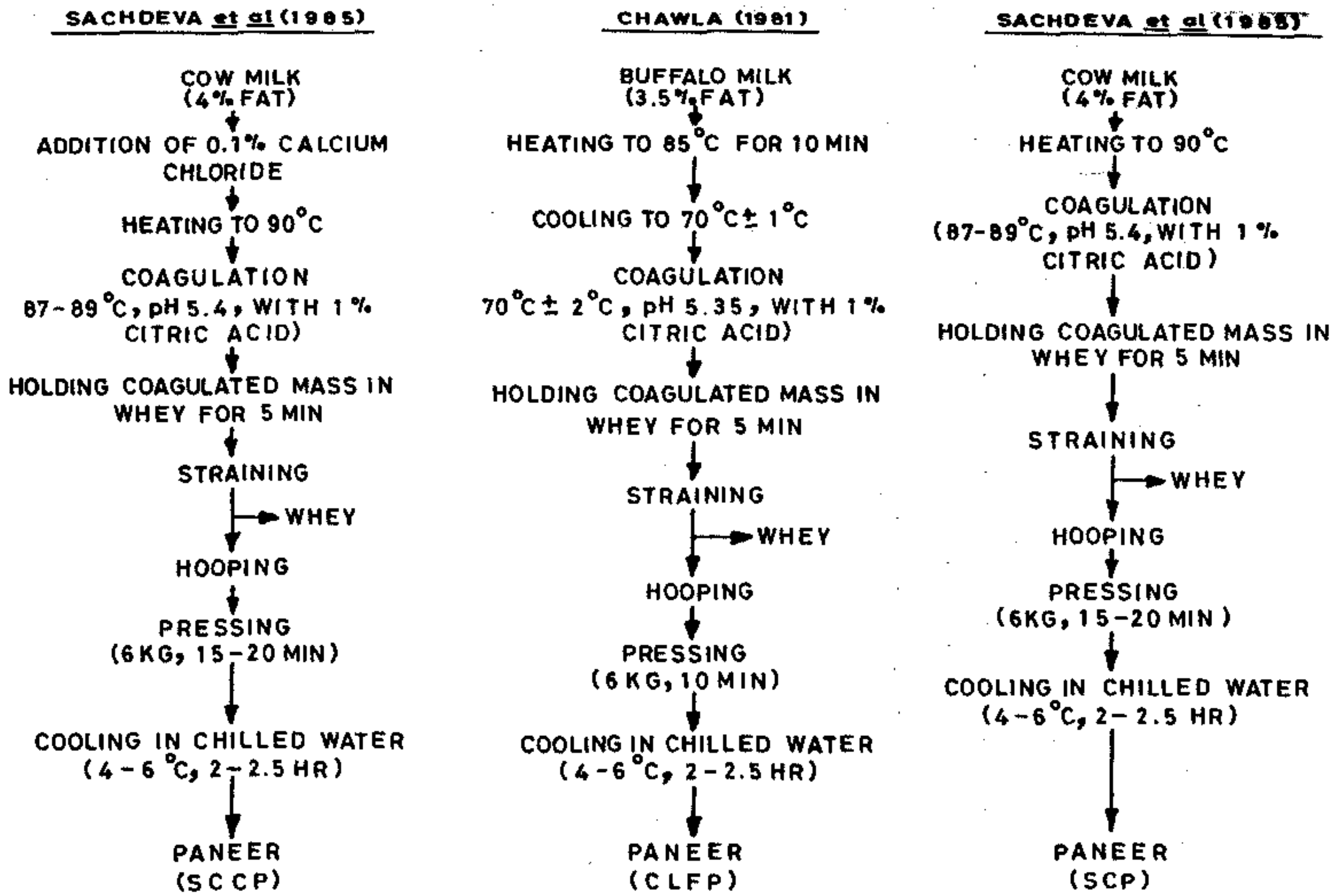


FIG.3.5 METHODS USED FOR MAKING PANEER FROM COW AND LOW FAT BUFFALO MILK

## 3.3 CHEMICAL ANALYSES

### 3.3.1 Preparation of Samples

3.3.1.1 Milk and Whey: A representative sample of milk (cow, buffalo or mixed milk, or skim milk) were drawn according to standard sampling methods and subjected to pH, total solids and fat determinations. Whey, similarly sampled, was analysed for pH.

3.3.1.2 Chhana and Paneer: Samples of chhana and raw paneer were prepared by grinding the representative portion of the product in a mortar and pestle till homogeneous mass was obtained.

3.3.1.3 Rasogolla and Fried and Cooked Paneer: Rasogolla and fried and cooked paneer held on a gauze were allowed to drain for about 5 min and ground as in case of chhana and paneer.

3.3.1.4 Sandesh: Sandesh samples were also prepared as described for chhana and paneer.

### 3.3.2 Total Solids

The total solids content was determined as follows: about 5g milk or 1 to 2g chhana, paneer, Rasogolla, Sandesh or fried and cooked paneer, was accurately weighed into a tared solids dish and dried in an electric oven at $102 \pm 1^{o}C$ to a constant weight and the solids content calculated in percent.

### 3.3.3 Fat

Fat in milk was determined by the Gerber method prescribed by ISI (1977).

The fat content of chhana and paneer was determined as per ISI (1980). The fat content of Rasogolla, Sandesh and fried and cooked paneer was determined with slight modification of the method prescribed in ISI (1980) wherein in place of 10 ml concentrated hydrochloric acid, 10 ml of 1:1 mixture of hydrochloric acid and water was used.

3.3.4 Total Protein

The total protein content of chhana, paneer, Rasogolla, Sandesh and fried and cooked paneer was estimated by the semi-micro kjeldahl method of Meneffee and Overman (1940) by taking 200-300 mg of accurately weighed sample. The total protein content was obtained by multiplying the total nitrogen with 6.38.

3.3.5 Ash

The ash content of the sample was estimated as follows: a sample of chhana, paneer or Rasogolla (about 3g) was accurately weighed into a tared silica crucible and dried in a hot air oven at 105°C. The dried sample was then ignited gently on a flame, ashed in a muffle furnace at 550° ± 20°C for 3 hr and weighed.

3.3.6 Total Carbohydrate

The total carbohydrate content of Rasogolla was calculated by difference as under:

Total carbohydrate % by weight = 100 - (% fat + % protein + % ash + % moisture)

### 3.3.7 Calcium

The calcium content of chhana and paneer samples was determined titrimetrically following the procedure given in ISI (1961) wherein ash (obtained in 3.3.5) was dissolved in 5 ml of 1:1 dil hydrochloric acid followed by addition 1 ml dil (1:1) nitric acid. The dissolved ash solution was transferred to a volumetric flask and the volume made up to 100 ml with distilled water. The solution was then filtered through Whatman No.40 filter paper. 25-30 ml of the filtrate was transferred to a 250 ml beaker and diluted to 100 ml with distilled water and 2 drops of methyl red solution (1g methyl red in 200 ml ethyl alcohol) added. Ammonium hydroxide solution (about 12.5%) was added dropwise till pH of the solution reached to 5.6 as shown by intermediate brownish orange colour. The pH was then lowered to 2.5-3.0 by dropwise addition of hydrochloric acid (1:3) till colour changed to pink. The contents were diluted to 150 ml, brought to boil and 10 ml hot saturated ammonium oxalate solution was added. The mixture was left to stand for 3 hr or longer, and the clear solution decanted through a Whatman No.42 filter-paper. The precipitate was washed with warm distilled water until it became chloride-free. The apex of the filter cone was punctured and calcium oxalate precipitate washed into the beaker used for precipitation, with 25 ml of hot sulphuric acid (1:4) and titrated at 85 to 90$^{\circ}$C with 0.05 M potassium permanganate solution. The calcium content was calculated as under.

$$\text{Calcium, \% by wt} = \frac{10\,X}{VW}$$

where,

X = volume in millilitres of 0.05 M potassium permanganate

V = volume in millilitres of ash (filtered) solution

W = weight in g of the sample taken for ashing

### 3.3.8 Phosphorus

The phosphorus content of chhana and paneer was determined using the ash solution (prepared as per 3.3.7) by the method of Fiske and Subba Row (1925), wherein 0.1 ml of the ash solution, 0.4 ml of 5 N sulphuric acid, 0.8 ml of ammonium molybdate reagent (2.5% W/V) and 0.4 ml of 1-amino-2-napthol-4-sulphonic acid reagent (prepared by dissolving 0.25 g of mixture consisting of 0.2 g 1-amino-2-napthol-4-sulphonic acid, 1.2 g sodium metabisulphite and 1.2 g sodium sulphite, in 10 ml distilled water) were added. The final volume of the mixture was made to 10 ml and mixed thoroughly. After 10 min incubation at ambient temperature, the colour intensity was measured at 700 nm employing the Spectronic 20 colorimeter (Bausch and Lomb, USA). The standard curve for phosphorous was prepared under identical conditions using potassium dihydrogen orthophosphate, taking phosphorus in the range of 10 to 100 $\mu$g/10 ml solution. Based on the data of standard curve a regression equation was computed;

$$\text{Concentration of phosphorus in } \mu g = 65.963 \times \text{O.D.} + 0.2544$$

where, O.D. = optical density of the tested sample.

The phosphorus content was expressed in %.

### 3.3.9 Determination of pH

pH of milk, whey, paneer or chhana was measured using an ELTOP pH meter (Punjab State Electronics Corpn. Ltd., Mohali) calibrated with standard buffer solution at 20°C. The glass electrode was inserted into the respective representative sample and the pH value obtained on a digital readout (Kosikowski, 1982).

### 3.3.10 Expressible Syrup of Rasogolla

A piece of Rasogolla previously allowed to rest on a wire gauze for about 5 min to effect drainage of loose syrup from the surface was transferred to another wire gauze and pressed for 5 min, using a 500 g dead weight. The expressed syrup collected in a tared aluminium dish was weighed and results expressed as g (of expressible syrup) per 100 g of (drained) Rasogolla.

## 3.4 OBJECTIVE TEXTURE MEASUREMENT

Objective textural properties of chhana, paneer, Rasogolla, and fried and cooked paneer, in terms of hardness, cohesiveness, springiness, gumminess and chewiness, were determined by Uniaxial double-cycled compression using an Instron Universal Testing Machine (Model 4301, Instron Ltd., U.K.) (Fig.3.6) attached with a strip chart recorder and printer.

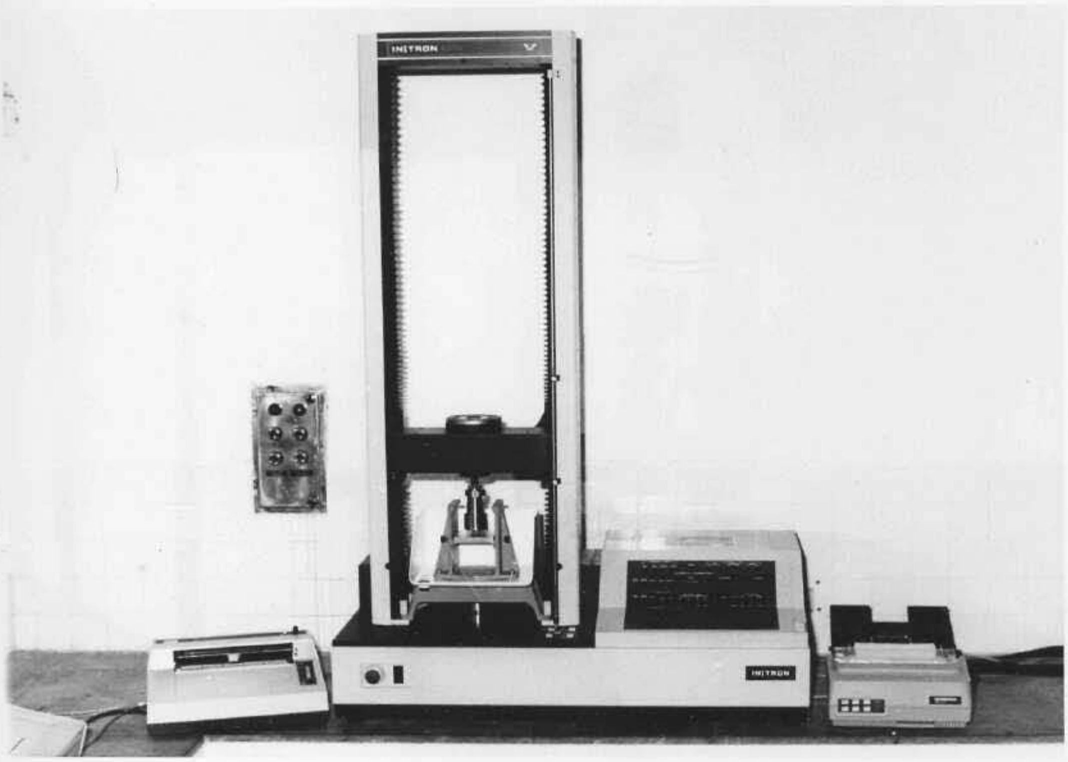

FIG. 3.6 INSTRON UNIVERSAL TESTING MACHINE
MODEL – 4301

3.4.1 Measurement by Instron

3.4.1.1 Testing Conditions: Based on relevant literature reports, the following test conditions were employed.

3.4.1.1.1 Sample size: Cylindrical sample of 1.9 cm diameter (cross sectional area, 2.84 $cm^2$) and 2 cm height was used in case of chhana, paneer and Rasogolla.

In case of fried and cooked paneer the exact cross sectional area was determined for each sample since the dimensions of the paneer plug changed, upon frying and cooking, to varying degrees.

3.4.1.1.2 Percent Compression: High levels of deformations (80% compression) have been suggested by some workers for texture evaluations that are to be correlated with sensory assessment (Breene, 1975; Gupta et al., 1984 and Bourne, 1978). However, Shinin (1987) suggested that high levels of strain resulted in almost complete destruction of the structural integrity of the sample (cheese) and thus it would be related more to oral texture evaluation rather than to evaluation by hand measurements such as pressing the sample with fingers, as was the case in the present investigation. Further, Boyd and Sherman (1975) also observed that moderate levels of strain, at fairly slow rates, were applied when panelist evaluate "body" or texture, using hand measurements in contrast to oral evaluations. Shinin (1987) obtained consistent results when cheese texture was evaluated under levels of strain that did not greatly exceed the fracture or yield value of cheese. Since the present instrumental analysis aimed at imitating screened panelists low levels of compression viz. 20% (i.e. compression to 80% of initial height) was considered more appropriate.

In preliminary tests, chhana samples were subjected to 10-80% compression. Force required to attain the desired strain was plotted against percent compression (Fig. 3.7). It was revealed that fracture occured at about 20% compression. Therefore, 20% compression was selected for the present study to determine non-destructive texture profile expected to correlate better with sensory data.

3.4.1.1.3 Load Cell: A 100 N load cell was used with the full scale deflection of the strip chart recorder set at 10 N for market and laboratory paneer samples and laboratory chhana samples, and at 5 N for market chhana samples and all samples of Rasogolla and fried and cooked paneer.

3.4.1.1.4 Crosshead Speed: A crosshead speed of 5 cm/min was used throughout the study as suggested by Breene (1975) for cheese.

3.4.1.1.5 Chart Speed: A chart speed of 10 cm/min was used.

3.4.1.1.6 Test Temperature: All Instron measurements were carried out at 15°C after tempering the samples overnight at this temperature.

3.4.1.2 <u>Interpretation of Texture Profile Parameters from Instron Curves</u>: A typical force-deformation curve obtained for double-cycled compression has been given

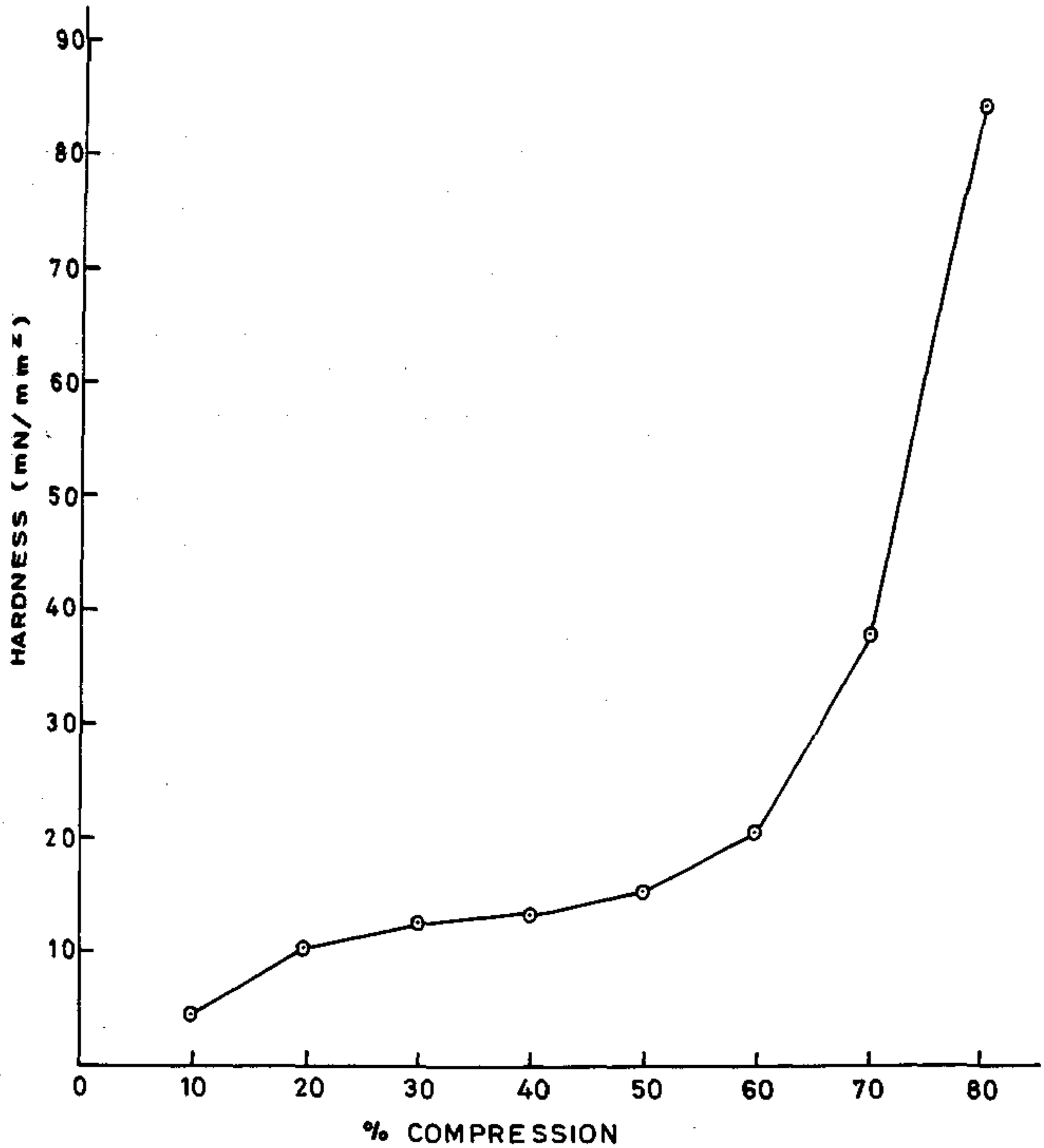


FIG.3.7 FORCE DEFORMATION CURVE FOR CHHANA : CYLINDRICAL SAMPLE (1.9 cm dia, 2 cm h.), CROSS HEAD SPEED 5 cm $min^{-1}$

in Fig. 3.8, and the parameters measured therefrom (Brady *et al*., 1985) included;

| | | |
|---|---|---|
| Hardness | - | Maximum force recorded during the first compression cycle (mN) |
| Cohesiveness | - | Area under curve $A_2$/area under curve $A_1$ |
| Springiness | - | Width of the downstroke in curve - $A_2$, mm |
| Gumminess | - | Hardness x cohesiveness, mN |
| Chewiness | - | Gumminess x springiness, mN.mm |

Since the response of the instrument in respect of adhesiveness (as indicated by a negative peak following the first peak) was negligible, this parameter was excluded.

### 3.4.2 Cone Penetration

The objective hardness of Sandesh was estimated by cone penetration as follows: The whole piece of Sandesh tempered overnight at 15$^{\circ}$C was placed on the movable platform of the cone penetrometer (plate 3.2) (Central Ignition Co., London) keeping point of penetration at the centre. The platform was so adjusted that tip of the cone just touched the sample. The cone assembly was allowed to descend into the sample for exactly 5 sec, and then depth of penetration was readout in 0.1 mm on the circular scale. This was converted into hardness by using the following formulae (Vasic and de Man, 1968).

$$H = \frac{G \times 10^3}{\left(h \times \pi \times \frac{\tan\alpha}{\cos\alpha} \times \left(\frac{h + 2r}{\tan\alpha}\right) + r^2\right) \times 10^4}$$

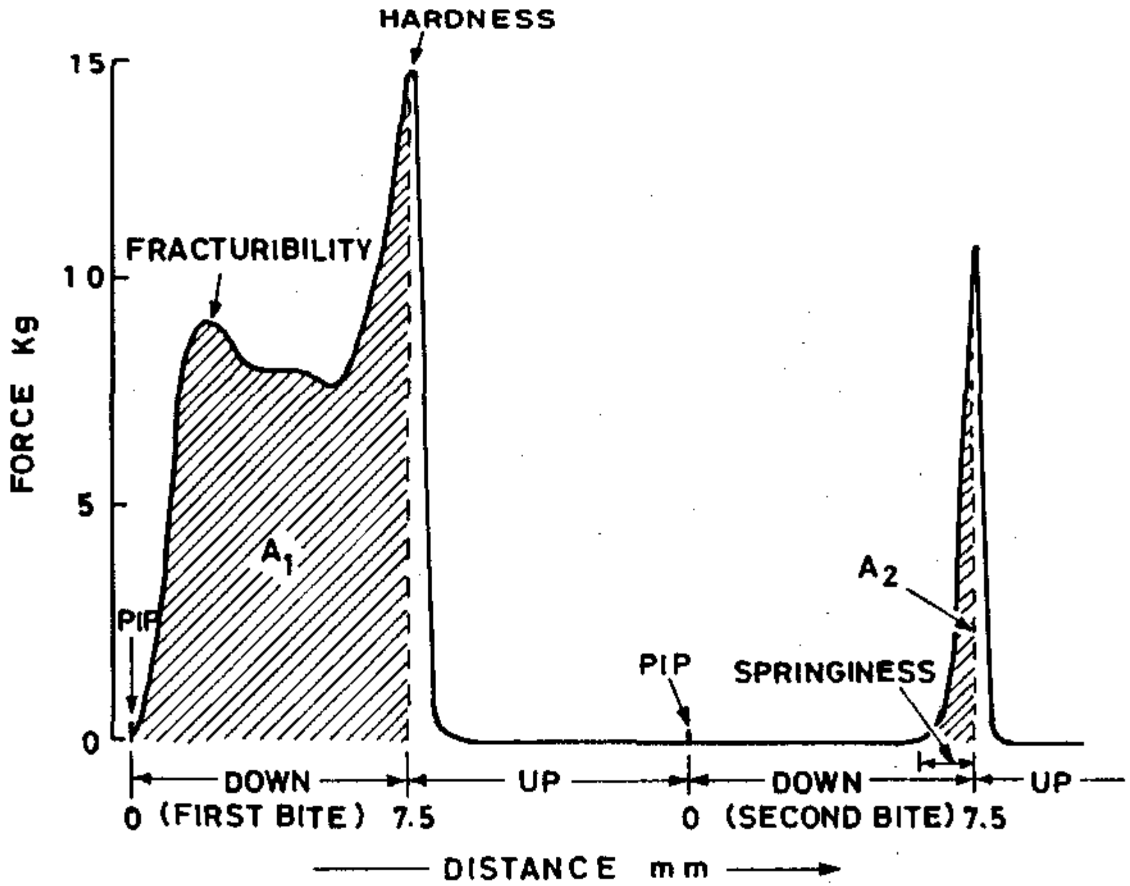


FIG. 3.8 TYPICAL SHAPE OF TPA CURVE OBTAINED BY AN INSTRON UNIVERSAL TESTING MACHINE WITH PROFILE PARAMETERS INDICATED

(SOURCE: BOURNE, 1968)

where,

H = Hardness in $kg/cm^2$

G = Weight of cone assembly in mg ( = 92,000)

h = Depth of penetration in 0.1 mm

$\alpha$ = half angle of cone ( = $10^{0}$)

r = Radius of the flat tip of the cone in 0.1 mm (r = 4)

## 3.5 SENSORY EVALUATION

Samples of chhana, paneer, fried and cooked paneer, Rasogolla and Sandesh were tempered overnight at $15^{0}$C before subjecting them to sensory evaluation. The size and shape of the samples were same as used for objective texture measurement. Based on the preliminary screening considering interest, motivation and willingness of judges, a panel of six judges was selected. A rating scale (Fig. 3.3) in the form of a 14 cm horizontal dotted straight line with its left end indicating one parametric extreme (o) and the opposite end indicating the other extreme (100) was used for each attribute. Scoring was done by indicating the perceived intensity/acceptability by means of a small vertical line along the 100-point (100 dot) scale divided into four equal major sections. At a time six samples at most were given for sensory evaluation.

## 3.6 STATISTICAL ANALYSES

Data on compositional parameters were analysed using the randomized block design (RBD). Data on objective textural properties were analysed employing factorial design.

Sensory evaluation card for texture of________

To the panelist

Kindly evaluate the given samples for different properties using the scales given below. To indicate your judgement make a vertical line along the scale and give the respective sample number against the line.

1. Elasticity (least elastic) .................. Extremely elastic

2. Firmness (Too soft) ...................... Too hard

3. Crumbliness (least crumbly) ................. Extremely crumbly

4. Stickiness (least sticky) .................. Extremely sticky

5. Smoothness (Grainy/rough) .................. Extremely smooth

6. Juiciness (least juicy) .................. Extremely juicy

7. Chewiness (least chewy) .................. Extremely chewy

8. Overall textural quality (Undesirable) .................. Most desirable

Remarks (if any):

Signature

Date

Name

Fig. 3.9 Unstructured scale for texture evaluation of chhana/paneer/Rasogolla/Sandesh

The data on sensory textural properties were transformed into arc-sine values and then subjected to factorial analysis. The comparison of market and laboratory samples was made using RBD. Data on chemical composition, objective and subjective textural properties were also subjected to regression analysis. All these analyses were carried out as per the methods described by Snedecor and Cochran (1968).

# RESULTS

# AND

# DISCUSSION

# 4. RESULTS AND DISCUSSION

The present study was undertaken to elucidate the objective and sensory textural properties of market chhana, Rasogolla, Sandesh and paneer (raw as well as fried and cooked). Simultaneously, chhana and paneer were prepared in the laboratory using different methods reported in the literature and their textural characteristics were also assessed. The textural properties of the most desirable market chhana and market paneer samples and laboratory made products were then compared. Finally, the relationship among compositional and rheological properties, and sensory textural attributes were derived. The results during this investigation have been discussed in this chapter.

## 4.1 CHHANA

### 4.1.1 Market Chhana

4.1.1.1 Composition: Texture of chhana is governed by its composition e.g. moisture content (Ray and De, 1953). However, very little information is available on the compositional aspects of chhana sold in the market.

It can be seen from Table 4.1 that the moisture content of market chhana varied from 66.51 to 71.63%. Thus all samples except one (MC-1) were within the legal requirements for moisture content (Max. 70%). While MC-1 chhana had a significantly higher ($P < 0.05$) moisture

Table 4.1 Composition of market chhana

| Constituent | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | MC1 | MC2 | MC3 | MC4 | MC5 | MC6 | | |
| Moisture, % | 71.63 | 68.08 | 69.16 | 66.51 | 69.17 | 68.88 | 2.71* | 2.96 |
| Fat, % | 9.98 | 12.94 | 12.96 | 14.27 | 12.31 | 13.39 | 1.96 | - |
| Protein, % | 14.90 | 15.23 | 14.32 | 15.16 | 14.76 | 14.25 | 1.22 | - |
| Ash, % | 1.44 | 1.48 | 1.41 | 1.53 | 1.53 | 1.44 | 2.19 | - |
| Calcium, % | 0.45 | 0.48 | 0.44 | 0.47 | 0.46 | 0.42 | 1.98 | - |
| Phosphorus, % | 0.25 | 0.26 | 0.22 | 0.25 | 0.25 | 0.20 | 1.30 | - |
| pH of chhana | 5.79 | 5.83 | 6.11 | 5.83 | 5.93 | 6.02 | 8.54** | 0.12 |

Average of six replicates

[a] Refers to the Vendor/Supplier of chhana

* $P < 0.05$, ** $P < 0.01$

content than chhana MC-4 and MC-6, these five samples (MC-2 to MC-6) did not differ significantly among themselves (Table 4.1). The fat content ranged from 9.98 to 14.27%. The fat content of all samples was below the PFA standards i.e. was less than 50% on dry matter basis.

From the point of view of protein, ash, calcium and phosphorus content, the market samples of chhana did not exhibit any significant differences. However, there were significant variation ($P \angle 0.01$) in pH of samples, the range being 5.79 to 6.11. Such variations could presumably be due to differences in manufacturing conditions.

Kumar and Srinivasan (1982) had, however, observed much lower moisture (59.64 to 65.30%) and higher fat (14.28 to 18.37%), protein (16.02 to 17.88%) and ash (2.20 to 2.26%) contents in market chhana in their studies.

4.1.1.2 Textural Properties: It has been reported that quality of chhana-based sweet is decided by the textural attributes of chhana. Soft body and smooth texture are believed to be the most desirable textural attributes of chhana (Ray and De, 1953; Singh and Ray, 1977a, Iyer, 1978; Bhattacharya and Desraj, 1980a and Soni et al., 1980).

The sensory score for different textural attributes and concomitant instrumental textural properties have been presented in Table 4.2 and 4.3, respectively. It can be visualized from Table 4.2 that chhana with relatively low firmness, elasticity, crumbliness and chewiness, moderate stickiness and high smoothness score was rated most desirable with respect to the overall textural quality.

Table 4.2 Sensory score (max, 100) for textural characteristics of market chhana

| Attribute | Sample[a] | | | | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|---|---|---|
| | MC1 | MC2 | MC3 | MC4 | MC5 | MC6 | | |
| Elasticity | 36.37 | 35.80 | 32.03 | 36.03 | 34.95 | 32.57 | 0.53 | - |
| Firmness | 35.63 | 36.76 | 28.41 | 34.95 | 28.03 | 29.95 | 3.72** | 3.49 |
| Crumbliness | 53.30 | 49.90 | 43.21 | 47.09 | 38.62 | 34.18 | 6.56** | 4.49 |
| Stickiness | 47.17 | 46.04 | 51.45 | 46.98 | 54.44 | 54.55 | 1.96 | - |
| Smoothness | 55.99 | 66.72 | 69.47 | 64.99 | 69.25 | 56.25 | 7.42** | 3.72 |
| Chewiness | 37.53 | 33.60 | 27.21 | 34.77 | 28.27 | 27.44 | 4.28** | 3.65 |
| Overall textural quality | 58.29 | 65.28 | 68.80 | 67.35 | 70.10 | 70.48 | 5.70** | 3.17 |

Average of six replicates

[a] Represents the Vendor/Supplier from whom chhana was obtained

[b] Based on arc-sine values vide Appendix I

* $P < 0.05$, ** $P < 0.01$

Table 4.3 Instrumental textural properties of market chhana

| Attribute | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | MC1 | MC2 | MC3 | MC4 | MC5 | MC6 | | |
| Hardness, mN | 3.08 | 3.87 | 2.52 | 3.71 | 2.39 | 2.16 | 4.91** | 0.91 |
| Cohesiveness | 0.61 | 0.67 | 0.57 | 0.65 | 0.57 | 0.55 | 4.62** | 0.06 |
| Springiness, mm | 6.13 | 6.21 | 6.25 | 6.50 | 6.38 | 6.08 | 0.28 | - |
| Gumminess, mN | 1.89 | 2.58 | 1.44 | 2.43 | 1.36 | 1.20 | 6.80** | 0.63 |
| Chewiness, mN,mm | 12.73 | 16.90 | 9.19 | 16.35 | 8.80 | 7.71 | 5.05** | 5.04 |

Average of six replicates

[a] Refers to the Vendor/Supplier of chhana

* $P < 0.05$, ** $P < 0.01$

It can be observed from Table 4.2 and 4.3 that subjective and objective textural properties of chhana samples showed significant variations ($P < 0.01$) except for sensory elasticity and stickiness, and instrumental springiness. Significant differences among samples ($P < 0.01$) for all Instron parameters except cohesiveness, and all sensory attributes except elasticity ($P < 0.05$) and smoothness indicated the extent of textural variability of the market product, which might be apparently be accounted for by various production practices in addition to the differences in moisture content (vide 4.1.1.1).

Information on these textural properties of market chhana is not available in literature for comparison. Non-significant differences among the Instron determinants (duplicate) indicated that the samples under test were quite homogenous.

### 4.1.2 Cow Milk Chhana

4.1.2.1 **Composition:** As discussed earlier (vide 2.7.1), cow milk has generally been preferred to buffalo milk for chhana manufacture. Various methods have been reported for manufacturing acceptable quality chhana from cow milk. Chhana was made by using some of these methods (vide Table 3.1) and its texture was characterized. While the composition of these products have been presented in Table 4.4, their sensory and instrumental textural characteristics are given in Table 4.5 and 4.6, respectively.

Table 4.4 Average composition of cow milk chhana

| Constituent | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | SC | BDC | DRC | KSC | SDC | IC | | |
| Moisture, % | 63.30 | 56.44 | 54.40 | 54.44 | 56.07 | 55.65 | 9.64** | 3.24 |
| Fat, % | 18.44 | 21.29 | 22.77 | 22.66 | 21.95 | 22.08 | 9.15** | 1.60 |
| Protein, % | 15.23 | 18.69 | 18.97 | 18.98 | 18.01 | 18.68 | 8.32** | 1.51 |
| Ash, % | 1.23 | 1.53 | 1.70 | 1.71 | 2.09 | 1.43 | 71.46** | 0.10 |
| Calcium, % | 0.37 | 0.45 | 0.50 | 0.50 | 0.60 | 0.45 | 69.21** | 0.05 |
| Phosphorus, % | 0.21 | 0.25 | 0.29 | 0.25 | 0.36 | 0.26 | 13.64** | 0.04 |
| pH of chhana | 6.03 | 5.86 | 5.81 | 5.89 | 6.22 | 5.53 | 115.95** | 0.07 |

Average of four replicates

[a] Refers to the method of manufacture vide Fig. 3.1

* $P < 0.05$, ** $P < 0.01$

Method SC produced chhana with significantly higher ($P < 0.01$) moisture and lower fat and protein contents as compared to chhana obtained by the rest of the methods (Table 4.4), differences among other samples generally being non significant. The method employed to manufacture sample SC (wherein lower acid strength 0.5%, lower temperature 70°C and higher pH 5.7 to effect coagulation, and holding the coagulum in whey for about 30 min before draining of whey) seemed to result in greater water retention in the product. The literature values for composition of cow milk chhana made by SC method are not available for comparison. However, Soni et al. (1980) observed 61.99% moisture in chhana made from buffalo milk using this method. While the moisture content of SC chhana was fairly close to the values for market chhana as reported by Kumar and Srinivasan (1982), but appreciably lower than the moisture content of market chhana as observed in the present study.

4.1.2.2 Textural Quality: The sensory and objective textural properties of cow milk chhana obtained by different methods have been presented in Table 4.5 and 4.6, respectively.

It is evident from Table 4.5 that SC chhana possessed lower firmness, elasticity and chewiness as compared to other chhana samples, the difference being highly significant ($P < 0.01$). SC chhana was moderately crumbly and somewhat more sticky than other samples. Its smoothness greatly exceeded those of other samples. Its

Table 4.5 Sensory textural properties (max.score, 100) of cow milk chhana

| Attribute | Sample[a] | | | | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|---|---|---|
| | SC | BDC | DRC | KSC | SOC | IC | | |
| Elasticity | 39.14 | 63.41 | 68.49 | 70.07 | 69.41 | 63.90 | 20.90** | 4.20 |
| Firmness | 30.46 | 55.92 | 58.94 | 68.18 | 65.00 | 50.31 | 32.81** | 3.88 |
| Crumbliness | 53.92 | 56.87 | 53.84 | 45.68 | 47.14 | 54.36 | 1.65 | - |
| Stickiness | 46.36 | 36.92 | 34.83 | 34.33 | 37.04 | 34.00 | 3.94** | 3.84 |
| Smoothness | 78.58 | 66.31 | 54.33 | 63.98 | 49.23 | 55.80 | 28.49** | 3.36 |
| Chewiness | 23.85 | 48.50 | 53.05 | 51.38 | 55.24 | 42.80 | 20.52** | 4.29 |
| Overall textural quality | 78.71 | 62.21 | 54.17 | 57.10 | 54.39 | 58.96 | 25.68** | 3.15 |

Average of four replicates

[a] Refers to the method of manufacture vide Fig. 3.1

[b] Based on arc-sine values vide Appendix II

* $P < 0.05$, ** $P < 0.01$

Table 4.6 Objective texture profile of cow milk chhana

| Attribute | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | SC | BDC | DRC | KSC | SDC | IC | | |
| Hardness, mN | 5.59 | 16.15 | 20.38 | 19.48 | 22.26 | 15.21 | 22.11** | 3.65 |
| Cohesiveness | 0.68 | 0.71 | 0.71 | 0.70 | 0.72 | 0.69 | 2.15 | - |
| Springiness, mm | 6.50 | 6.56 | 6.88 | 7.06 | 7.19 | 6.44 | 0.89 | - |
| Gumminess, mN | 3.74 | 11.54 | 14.63 | 13.77 | 16.19 | 10.44 | 23.65** | 2.61 |
| Chewiness, mN.mm | 24.85 | 75.72 | 99.41 | 98.39 | 166.19 | 65.55 | 16.05** | 23.37 |

Average of four replicates

[a] Refers to the method of manufacture vide Fig.3.1

* P ∠ 0.05, ** P ∠ 0.01

overall textural quality was also significantly higher ($P < 0.01$) than that of other samples. The sensory data appeared to be well supported by instrumental measurements, the hardness and chewiness values being significantly ($P < 0.01$) lower for SC than for others. The observed differences among BDC, DRC, KSC, SDC and IC were not appreciable although the overall sensory score for BDC was significantly ($P < 0.01$) better than for DRC, KSC, SDC and IC. The striking differences between SC chhana and other samples (BDC, DRC, KSC, DSC and IC) could be attributed to the corresponding differences in moisture content. Lower calcium content of SC (Table 4.4) could also be responsible in this regard. Jagtiani <u>et al</u>. (1971) also demonstrated that when more amount of calcium was added to cow milk, the chhana became harder.

### 4.1.3 Buffalo Milk Chhana

Basically buffalo milk differs from cow milk in its quantitative and qualitative compositional characteristics (Ganguli, 1974). Chhana produced from buffalo milk using the procedure standardized for cow milk produces a product which is qualitatively quite different from the latter. Many process modifications have been reported in literature to improve the quality of buffalo milk chhana. A few selected procedures, including the basic method of De and Ray (1954) (vide Table 3.2) were adopted to examine the textural properties of the resulting product.

4.1.3.1 Composition: Composition of chhana prepared from buffalo milk by different methods has been presented in Table 4.7. It is evident that DRBC chhana had the lowest moisture but highest fat, protein, ash, calcium and phosphorus contents, the differences being highly significant ($P < 0.01$). Samples SBC and KDBC showed the highest values for moisture had an intermediate fat content but the lowest protein, ash and calcium contents. These two chhana samples were moisture-wise similar to cow milk chhana (Table 4.4) except that of SC chhana. This indicated that the process modifications suggested for better moisture retention in the buffalo milk product were only partly effective. Thus buffalo milk chhana showed generally lower moisture and higher fat contents as compared to cow milk chhana.

4.1.3.2 Textural Characteristics: Several reports have appeared indicating that buffalo milk is not suitable for chhana making (De and Ray, 1954; Jagtiani et al., 1960 and Anantakrishnan and Srinivasan, 1964) presumably because of the low moisture retention capacity and consequently hard body and coarse texture of the resulting product.

As shown in Table 4.8, SBC chhana having considerably lower sensory firmess and chewiness, and greatly improved smoothness scored much better for its overall texture than other chhana samples. The elasticity and crumbliness of SBC were also significantly lower ($P < 0.01$) than the corresponding values for most other buffalo chhanas. Though it was more sticky. From the view point of overall

Table 4.7 Chemical composition of buffalo milk chhana

| Constituent | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | DRBC | KSBC | ICBC | IBC | SBC | KDBC | | |
| Moisture, % | 47.19 | 52.20 | 51.20 | 51.36 | 56.45 | 57.74 | 44.91** | 1.73 |
| Fat, % | 28.32 | 26.00 | 26.42 | 26.25 | 24.63 | 21.55 | 33.63** | 1.18 |
| Protein, % | 20.08 | 17.63 | 18.92 | 19.15 | 15.69 | 17.01 | 77.99** | 0.55 |
| Ash, % | 1.90 | 1.77 | 1.55 | 1.52 | 1.41 | 1.50 | 42.59** | 0.09 |
| Calcium, % | 0.64 | 0.57 | 0.53 | 0.53 | 0.44 | 0.52 | 36.06** | 0.03 |
| Phosphorus, % | 0.32 | 0.30 | 0.26 | 0.27 | 0.23 | 0.26 | 17.16** | 0.02 |
| pH of chhana | 5.60 | 5.95 | 5.54 | 5.67 | 5.98 | 5.85 | 32.53** | 0.09 |

Average of four replicates

[a] Refers to the method of manufacture vide Fig. 3.2

* $P < 0.05$, ** $P < 0.01$

Table 4.8 Average sensory score (max, 100) for textural attributes of buffalo milk chhana

| Attribute | Sample[a] | | | | | | F. ratio[b] | CD[b] |
|---|---|---|---|---|---|---|---|---|
| | DRBC | KSBC | ICBC | IBC | SBC | KDBC | | |
| Elasticity | 56.96 | 64.03 | 61.18 | 62.59 | 55.07 | 50.24 | 3.86** | 4.33 |
| Firmness | 77.67 | 68.99 | 64.25 | 69.67 | 37.58 | 73.97 | 41.05** | 3.73 |
| Crumbliness | 45.96 | 49.08 | 47.70 | 48.22 | 40.03 | 65.60 | 5.31** | 6.04 |
| Stickiness | 23.90 | 23.76 | 23.80 | 27.35 | 40.44 | 20.98 | 19.52** | 2.78 |
| Smoothness | 49.74 | 47.42 | 54.27 | 50.77 | 74.67 | 31.53 | 64.66** | 2.87 |
| Chewiness | 65.77 | 63.11 | 54.15 | 56.84 | 29.27 | 66.51 | 33.72** | 3.96 |
| Overall textural quality | 45.02 | 48.39 | 59.01 | 57.01 | 78.02 | 34.17 | 58.29** | 3.28 |

Average of four replicates

[a] Refers to the method of manufacture vide Fig. 3.2

[b] Based on arc-sine values vide Appendix III

* $P < 0.05$, ** $P < 0.01$

texture score, ICBC and IBC ranked next to SBC while the remaining samples were significantly ($P < 0.01$) less desirable. The manufacturing method, SBC, resulted in a product that had high moisture retention with desirable textural quality. The lowest texture score of KDBC having a slightly higher moisture content indicated that moisture alone was not the deciding factor for the texture of chhana but perhaps conditions of manufacture, which affected the crumbliness and smoothness of the product were equally important. The significantly lower ($P < 0.01$) calcium content of SBC chhana might also have played a definite role towards texture improvement.

Addition of sodium citrate to buffalo milk before coagulation (as for ICBC) seemed to improve the textural quality. The product had moderately lower firmness and chewiness and better smoothness (Table 4.8). This indicates that sodium citrate could modify the coagulation characteristics of buffalo milk and hence the textural properties of the resulting chhana.

In general, buffalo milk chhanas were more elastic, firm, crumbly and chewy, and were less sticky and less smooth as compared to cow milk and market chhana. These observations were supported by the higher Instron hardness, gumminess and chewiness of the buffalo milk product (Table 4.9). Differences in sensory attributes among buffalo milk chhanas were confirmed by Instron parameters especially the significantly lower ($P < 0.01$) hardness and chewiness values of SBC chhana.

Table 4.9 Instron texture profile analysis of buffalo milk chhana

| Attribute | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | DRBC | KSBC | ICBC | IBC | SBC | KDBC | | |
| Hardness, mN | 47.74 | 32.75 | 28.86 | 28.89 | 13.94 | 32.77 | 38.63** | 5.01 |
| Cohesiveness | 0.67 | 0.71 | 0.66 | 0.70 | 0.71 | 0.76 | 4.31** | 0.05 |
| Springiness, mm | 7.00 | 6.56 | 7.00 | 7.06 | 6.63 | 6.69 | 0.64 | - |
| Gumminess, mN | 31.53 | 23.28 | 18.67 | 20.09 | 9.81 | 24.53 | 36.91** | 3.41 |
| Chewiness, mN.mm | 227.10 | 159.17 | 137.99 | 142.43 | 68.22 | 168.83 | 15.39** | 37.79 |

Average of four replicates

[a] Refers to the method of manufacture vide Fig. 3.2

* $P < 0.05$, ** $P < 0.01$

Adverse effect of homogenization (Iyer, 1978) has been confirmed as KDBC chhana (vide Table 3.2) had the highest crumbliness, more firmness, highest chewiness and lowest smoothness (Table 4.8) with concomitant higher instrumental hardness, gumminess and chewiness (Table 4.9), giving rise to undesirable textural quality.

4.1.4 Mixed Milk Chhana

Admixing of cow and buffalo milk in an appropriate proportion could surmount the drawbacks of using only buffalo milk for chhana making as stated by De and Ray (1954). In the present study, three procedures (vide Table 3.3) were used employing buffalo milk mixed with cow milk.

4.1.4.1 Composition: Table 4.10 gives the composition of mixed milk chhana observed during the present investigation. Chhana (SMC) made by the method of Soni *et al.* (1980) had significantly ($P < 0.01$) higher moisture and lower fat, protein, ash and calcium contents as compared to IMC and DRMC. The moisture content of SMC was intermediate between SC and SBC, products made from cow and buffalo milks, respectively, using the same method. As the level of mixing of cow and buffalo milk (3:1) was same for both chhana SMC and DRMC, compositional differences can be attributed to manufacturing conditions.

4.1.4.2 Texture of Mixed Milk Chhana: The sensory and objective textural properties of mixed milk chhana have been presented in Table 4.11 and 4.12, respectively. Here

Table 4.10 Compositional attributes of mixed milk chhana

| Attribute | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | IMC | SMC | ORMC | | |
| Moisture, % | 51.68 | 61.10 | 51.56 | 160.56** | 1.31 |
| Fat, % | 24.66 | 19.81 | 24.80 | 136.29** | 0.74 |
| Protein, % | 19.83 | 15.92 | 20.20 | 149.18** | 0.59 |
| Ash, % | 1.72 | 1.33 | 1.52 | 39.43** | 0.09 |
| Calcium, % | 0.52 | 0.41 | 0.47 | 148.48** | 0.01 |
| Phosphorus, % | 0.32 | 0.21 | 0.25 | 51.64** | 0.02 |
| pH of chhana | 5.88 | 6.01 | 5.55 | 318.08** | 0.04 |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.3

* $P < 0.05$, ** $P < 0.01$

Table 4.11 Sensory textural assessment (max.score 100) of mixed milk chhana.

| Attribute | Sample[a] | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|
| | IMC | SMC | DRMC | | |
| Elasticity | 62.31 | 44.86 | 68.47 | 72.86** | 2.36 |
| Firmness | 64.75 | 34.53 | 69.26 | 153.89** | 2.49 |
| Crumbliness | 48.39 | 39.54 | 49.77 | 8.79** | 3.04 |
| Stickiness | 27.96 | 47.24 | 27.24 | 47.39** | 2.76 |
| Smoothness | 49.98 | 75.20 | 48.78 | 117.35** | 2.31 |
| Chewiness | 55.69 | 29.93 | 59.95 | 114.79** | 2.49 |
| Overall textural quality | 52.30 | 78.22 | 53.14 | 219.44** | 1.71 |

Average of eight replicates

a Refers to the method of manufacture vide Fig.3.3

b Based on arc-sine values vide Appendix IV

* $P < 0.05$, ** $P < 0.01$

Table 4.12 Instrumental textural attributes of mixed milk chhana

| Attribute | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | IMC | SMC | DRMC | | |
| Hardness, mN | 26.34 | 7.70 | 20.45 | 97.40** | 2.76 |
| Cohesiveness | 0.73 | 0.73 | 0.73 | 0.07 | - |
| Springiness, mm | 7.09 | 6.91 | 7.03 | 0.22 | - |
| Gumminess, mN | 18.33 | 5.57 | 14.72 | 129.27** | 1.71 |
| Chewiness, mN.mm | 139.30 | 40.33 | 108.32 | 48.93** | 20.73 |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig.3.3

* $P < 0.05$, ** $P < 0.01$

again the high-moisture SMC chhana having significantly ($P \angle 0.01$) lower elasticity, firmness, crumbliness and chewiness, and higher smoothness was texture-wise considerably more desirable than IMC and ORMC chhana, the latter two not appreciably differing from each other. The differences in sensory attributes were accompanied by significant ($P \angle 0.01$) differences in the instrumental parameters particularly hardness and chewiness.

### 4.1.5 Comparison Between Market and Laboratory Made Chhana

As seen earlier (vide 4.1.1) market chhana had generally more desirable textural properties than most of the laboratory made chhana. Considerable variations were observed in market samples. This must be due to different manufacturing techniques employed by the traders. Thus the market chhana observed to be the most desirable was considered as the standard product for comparing its textural properties with those of laboratory made chhana.

As evident from literature and duly substantiated by the results of the present investigation discussed earlier, good quality chhana should be soft (low firmness score) and smooth and should have low degree of chewiness, crumbliness and elasticity.

Thus it can be inferred from Table 4.2 that of all the market chhanas studied, MC-5 and MC-6 had the most desirable textural quality attributes were scored nearly good. However, the sample MC-5 had significantly

($P < 0.01$) better score for smoothness, which is apparently one of the most important textural attributes. Therefore, this product was chosen for comparative rating of laboratory made chhana.

4.1.5.1 Comparison Between Market and Cow Milk

• Chhana: As seen from Table 4.13 all laboratory samples of chhana except SC were, in general, significantly ($P < 0.01$) more elastic, firmer, crumblier, smoother but less chewy. Chhana sample SC was significantly ($P < 0.01$) more smooth, less chewy and less sticky and appreciably more crumbly than the market samples. On the basis of firmness and elasticity, SC was at par with MC-5. Instrumentally measured hardness, cohesiveness and chewiness (Table 4.14) confirmed the sensory data, that the market chhana was more desirable in these aspects as compared to laboratory chhana, although laboratory SC chhana was much more closer to market sample MC-5. It should however be noticed that all laboratory chhana except SC were scored significantly ($P < 0.01$) lower than market chhana. On the basis of elasticity, firmness (Instron hardness), smoothness and chewiness BDC chhana was generally less desirable than SC but more desirable than other laboratory chhana. Overall sensory texture score for BDC was appreciably better than that for DRC, KSC, SDC and IC chhana, but still significantly ($P < 0.01$) lower than the score of market chhana.

It can be concluded that none of the methods of chhana making from cow milk produced chhana with objective textural properties identical to the one observed for MC-5

Table 4.13 Comparison of sensory textural profiles (max.score, 100) of market chhana and cow milk chhana

| Attribute | Sample | | | | | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|---|---|---|---|
| | MC5 | SC | BDC | DRC | KSC | SDC | IC * | | |
| Elasticity | 33.66 | 39.14 | 63.41 | 68.49 | 70.07 | 69.41 | 63.90 | 32.47** | 4.39 |
| Firmness | 29.86 | 30.46 | 55.92 | 58.94 | 68.18 | 65.00 | 50.31 | 39.41** | 4.07 |
| Crumbliness | 37.82 | 53.92 | 56.87 | 53.84 | 45.68 | 47.14 | 54.36 | 3.60** | 5.73 |
| Stickiness | 55.94 | 46.36 | 36.92 | 34.83 | 34.33 | 37.04 | 34.00 | 11.60** | 3.93 |
| Smoothness | 68.02 | 78.58 | 66.31 | 54.33 | 63.98 | 49.23 | 55.80 | 23.80** | 4.27 |
| Chewiness | 28.26 | 23.85 | 48.50 | 53.05 | 51.38 | 55.24 | 42.80 | 23.08** | 2.50 |
| Overall textural quality | 68.03 | 78.71 | 62.21 | 54.17 | 57.10 | 54.39 | 58.96 | 19.87** | 3.41 |

Average of four replicates (selected randomly from total 6 for MC5 vide Table 4.2)

[b] Based on arc-sine values vide Appendix V

* $P < 0.05$, ** $P < 0.01$

Table 4.14 Comparison of Instrumental textural attributes of market chhana with cow milk chhana

| Attribute | Sample | | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|---|
| | MC5 | SC | BDC | DRC | KSC | SDC | IC | | |
| Hardness, mN | 2.43 | 5.59 | 16.15 | 20.38 | 19.48 | 22.26 | 15.21 | 22.65** | 4.75 |
| Cohesiveness | 0.56 | 0.68 | 0.71 | 0.71 | 0.70 | 0.72 | 0.69 | 9.44** | 0.05 |
| Springiness, mm | 6.13 | 6.50 | 6.56 | 6.88 | 7.06 | 7.19 | 6.44 | 0.65 | - |
| Gumminess, mN | 1.35 | 3.74 | 11.54 | 14.63 | 13.77 | 16.19 | 10.44 | 22.60** | 3.52 |
| Cheuiness, mN.mm | 8.55 | 24.65 | 75.72 | 99.42 | 98.39 | 166.19 | 65.55 | 16.10** | 29.37 |

Average of four replicates (selected randomly from total 6 for MC5 vide Table 4.2)

* P $\angle$ 0.05, ** P $\angle$ 0.01

market chhana. However, method SC seemed to be the closest amongst the methods based on the data on sensory evaluation.

4.1.5.2 Comparison Between Market and Buffalo Milk Chhana: As can be visualized from Table 4.15, all chhana from buffalo milk, except SBC, were significantly ($P < 0.01$) firmer, less smooth but more chewy than market samples. Crumbliness of all chhana samples, was at par with market chhana except KDBC which was most crumbly. Sample SBC was significantly ($P < 0.01$) more sticky than rest of the chhana from buffalo milk, but significantly ($P < 0.01$) less so when compared with market chhana. All buffalo milk chhana were significantly ($P < 0.01$) more elastic than market ones, though DRBC, SBC and KDBC had similar elasticity values. KSBC chhana was the most elastic. On the basis of firmness, smoothness and chewinesswise, SBC chhana was much closer to market chhana. Instron textural measurement in terms of hardness, cohesiveness and chewiness (Table 4.16) substantiated these observations. The overall sensory texture score of SBC chhana was observed to be significantly ($P < 0.01$) superior to market chhana. The rest of buffalo milk chhana were however significantly ($P < 0.01$) less desirable than market samples. All the chhana were more or less similar in their objective as well as subjective textural characteristics, except sample SBC.

4.1.5.3 Comparison Between Market and Mixed Milk Chhana: Mixed milk chhana (SMC) was quite comparable

Table 4.15 Comparison of sensory texture attributes (max.score,100) between market chhana and buffalo milk chhana

| Attribute | Sample | | | | | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|---|---|---|---|
| | MC5 | DRBC | KSBC | ICBC | IBC | SBC | KDBC | | |
| Elasticity | 33.66 | 56.96 | 64.03 | 61.18 | 62.59 | 55.07 | 50.24 | 13.58** | 4.63 |
| Firmness | 29.86 | 77.67 | 68.99 | 64.25 | 69.67 | 37.58 | 73.97 | 62.83** | 3.93 |
| Crumbliness | 37.82 | 45.96 | 49.08 | 47.70 | 48.22 | 40.03 | 65.60 | 5.41** | 6.27 |
| Stickiness | 55.94 | 23.90 | 23.76 | 23.80 | 27.35 | 40.44 | 20.98 | 49.65** | 3.06 |
| Smoothness | 68.02 | 49.74 | 47.42 | 54.27 | 50.77 | 74.67 | 31.53 | 60.05** | 3.03 |
| Chewiness | 28.26 | 65.77 | 63.11 | 54.15 | 56.84 | 29.27 | 66.51 | 47.51** | 3.94 |
| Overall textural quality | 68.03 | 45.02 | 48.39 | 59.01 | 57.01 | 78.02 | 34.17 | 48.77** | 3.50 |

Average of four replicates (selected randomly from total 6 for MC5 vide Table 4.2)

[b] Based on arc-sine values vide Appendix VI

* $P < 0.05$, ** $P < 0.01$

Table 16: Comparison of instrumental textural properties of market chhana with buffalo milk chhana

| Attribute | Sample | | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|---|
| | MC5 | DRBC | KSBC | ICBC | IBC | SBC | KDBC | | |
| Hardness, mN | 2.43 | 47.74 | 32.75 | 28.86 | 28.89 | 13.94 | 32.77 | 37.70** | 8.37 |
| Cohesiveness | 0.56 | 0.67 | 0.71 | 0.66 | 0.70 | 0.71 | 0.76 | 8.37** | 0.06 |
| Springiness, mm | 6.13 | 7.00 | 6.56 | 7.00 | 7.06 | 6.63 | 6.68 | 0.74 | - |
| Gumminess, mN | 1.35 | 31.53 | 23.28 | 18.67 | 20.09 | 9.81 | 24.53 | 40.89** | 4.65 |
| Chewiness, mN.mm | 8.55 | 227.10 | 159.17 | 137.99 | 142.43 | 68.22 | 168.83 | 14.23** | 56.13 |

Average of four replicates (selected randomly from total 6 for MC5 vide Table 4.2)

* $P < 0.05$, ** $P < 0.01$

to market chhana in terms of firmness, crumbliness and chewiness (Table 4.17). In fact on the basis of smoothness it was significantly ($P < 0.01$) better than even market chhana. SMC chhana was also significantly ($P < 0.01$) superior to IMC, DRMC and market chhana in overall textural quality. However, IMC and DRMC were more or less similar in their sensory textural properties and did not seem to so desirable from the overall textural quality point of view. The Instron data (Table 4.18) indicated that hardness, cohesiveness, chewiness and gumminess of all mixed milk chhana were significantly ($P < 0.01$) greater than market chhana, although the values for SMC were appreciably closer to market samples. The sensory and Instron textural values of SMC were between those of SC and SBC.

It can thus be concluded that among all the methods employed in the present study, SC, SBC and SMC were found to produce a chhana that was closer to market chhana on the basis of textural characteristics. Closer examination of SC, SBC and SMC methods reveals that these methods (of manufacture of all 3) were identical except that cow, buffalo and mixed milks have been used, respectively. The salient feature of the method of manufacture was that after coagulation at 70$^{o}$C, pH 5.7 with 0.5% lactic acid the coagulum was allowed to cool in its own whey for 30 min. This might have enhanced the water-retention capacity of chhana without adversely affecting the smoothness, thereby improving the texture.

Table 4.17 Comparison of sensory textural properties (max.score,100) between market chhana and mixed milk chhana

| Attribute | Sample | | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|---|
| | MC5 | IMC | SMC | DRMC | | |
| Elasticity | 33.66 | 64.38 | 48.59 | 68.37 | 40.07** | 4.13 |
| Firmness | 29.86 | 64.19 | 32.61 | 65.51 | 51.99** | 4.47 |
| Crumbliness | 37.62 | 46.88 | 33.75 | 45.45 | 4.13** | 5.07 |
| Stickiness | 55.94 | 28.76 | 46.79 | 26.94 | 31.65** | 4.18 |
| Smoothness | 68.02 | 50.85 | 75.01 | 51.27 | 32.61** | 3.58 |
| Chewiness | 28.26 | 50.76 | 30.44 | 55.79 | 37.29** | 3.80 |
| Overall textural quality | 68.03 | 53.32 | 78.63 | 55.04 | 37.95** | 3.41 |

Average of four replicates (selected randomly from total 6 for MC5 vide Table 4.2, and from 8 for IMC, SMC and DRMC vide Table 4.11)

[b] Based on arc-sine values vide Appendix VII

* $P < 0.05$, ** $P < 0.01$

Table 4.18 Comparison of instrumental texture profile between market and mixed milk chhana

| Attribute | Sample | | | | F.ratio | CD |
|---|---|---|---|---|---|---|
| | MC5 | IMC | SMC | DRMC | | |
| Hardness, mN | 2.43 | 21.64 | 6.18 | 16.21 | 109.63** | 2.71 |
| Cohesiveness | 0.56 | 0.76 | 0.73 | 0.74 | 19.82** | 0.07 |
| Springiness, mm | 6.13 | 6.38 | 5.69 | 6.13 | 0.50 | - |
| Gumminess, mN | 1.35 | 16.50 | 4.47 | 12.02 | 107.10** | 2.14 |
| Chewiness, mN.mm | 8.55 | 105.04 | 25.89 | 74.58 | 57.50** | 10.68 |

Average of four replicates (selected randomly from total 6 for MC5 vide Table 4.2, and from 8 for IMC, SMC and DRMC vide Table 4.11)

* $P < 0.05$, ** $P < 0.01$

### 4.1.6 Relationship between Rheological, Sensory and Compositional attributes of Chhana

Since texture is a sensory property of foods that results from a multifaceted group of physical components (Bourne, 1978), attempts have frequently been made to relate this quality attribute (as evaluated by human panelists) to the mechanical, geometrical and moisture-fat characteristics of the product especially in the case of cheese (Thomas et al., 1970; Keller et al., 1974; Lee et al., 1978; Imoto et al., 1979; Perry and Carroad, 1980; Green et al., 1985 and Green et al., 1986).

Investigations of instrumental procedures to provide descriptions of the textural attributes of a product are generally intended to overcome the disadvantages of expense and time associated with sensory texture profiling. Instrumental texture profile analysis can be extremely useful in evaluating the textural quality of foods, however, the usefulness of any instrumental procedure is limited by its relationship to sensory assessment, since texture is by defination a sensory characteristic (Szczesniak, 1963). Once this relationship is established, sensory textural characteristics could be predicted based on instrumental texture profile. This can be further simplified by seeking relationships between instrumental texture profile and composition of the product, which enable us to predict former from the latter.

The pooled data on sensory and instrumental textural properties as well as on composition of chhana were subjected to correlation and regression analyses to seek possible relationship among them.

4.1.6.1 Relationships between Instrumental and sensory Rheology: An attempt was made to establish a relationship between sensory and instrumental rheological properties to replace the tedious and time consuming sensory evaluation, by assessing the product's texture by objective means. The coefficients of simple correlations between the instrumental and sensory textural properties of chhana have been presented in Table 4.19.

Instrumental hardness of chhana showed direct linear relationships ($P \angle 0.01$) with sensory elasticity, firmness, crumbliness and chewiness, and an inverse relationship ($P \angle 0.01$) with stickiness, smoothness and overall textural quality. Thus as hardness increased, chhana become less sticky, less smooth and less acceptable in terms of overall texture. Instron cohesiveness, gumminess and chewiness followed similar pattern of relationship with all sensory textural properties as observed for hardness. However, the degree of correlation with the sensory parameters was somewhat smaller for cohesiveness while that for gumminess and chewiness was similar as for hardness. Springiness of chhana showed positive correlation with elasticity ($P \angle 0.05$) as well as firmness, crumbliness and chewiness ($P \angle 0.01$) but not with other sensory attributes. Highly significant negative correlation of

Table 4.19 Coefficients of correlation[a] (simple) between Instron and sensory textural properties of chhana

| Attribute | Hardness (H) | Cohesiveness (Co) | Springiness (Sp) | Gumminess (Gu) | Chewiness (Ch) |
|---|---|---|---|---|---|
| Elasticity (SE) | 0.66** | 0.58** | 0.24* | 0.68** | 0.64** |
| Firmness (SF) | 0.85** | 0.50** | 0.25** | 0.96** | 0.80** |
| Crumbliness (SCR) | 0.32** | 0.26** | 0.32** | 0.33** | 0.35** |
| Stickiness (SST) | -0.76** | -0.56** | -0.15 | -0.78** | -0.70** |
| Smoothness (SSM) | -0.63** | -0.25** | -0.10 | -0.65** | -0.60** |
| Chewiness (SCH) | 0.85** | 0.47** | 0.34** | 0.86** | 0.82** |
| Overall textural quality (SOTQ) | -0.70** | -0.32** | -0.07 | -0.72** | -0.67** |

[a] Based on 108 observations

* $P < 0.05$, ** $P < 0.01$

Instron hardness with overall textural quality indicated that softness was the most desirable sensory attribute of chhana.

Lee et al. (1978) while correlating sensory and instrumental texture of wide varieties of soft and semi-hard cheeses obtained better correlations between sensory hardness and springiness, and Instron hardness and elasticity, respectively.

Regression equations (Table 4.20) clearly show that Instron hardness alone could explain most of the variation in different sensory properties. However, hardness coupled with cohesiveness and springiness could appreciably enhance the predictability of sensory elasticity and chewiness. The log linear relationship between sensory firmness and objective hardness of chhana has been shown in Fig. 4.1. It can be further seen from the Table 4.20 that all sensory attributes, except chewiness, showed the best fit for a straight line curve when expressed as logarithmic values. Chewiness was better explained by instrumental hardness, cohesiveness and springiness taken together and expressed as such, although a quadratic relationship between sensory chewiness and Instron chewiness (Fig. 4.2) could also explain the variability of sensory chewiness to nearly the same extent.

4.1.6.2 Relationship between Instrumental Textural Attributes and Compositional Parameters of Chhana: Such relationships can serve as an important quality control tool to predict the textural quality

Table 4.20 Regression equations between objective and subjective textural properties of chhana

| Equation | $R^2$ |
|---|---|
| $\ln SE = 3.32 + 0.25 \ln H$ | 0.68 |
| $\ln SE = 3.77 + 0.23 \ln H + 0.47 \ln Co - 0.11 \ln SP$ | 0.71 |
| $\ln SF = 3.09 + 0.33 \ln H$ | 0.79 |
| $\ln SF = 3.51 + 0.36 \ln H - 0.13 \ln Co - 0.29 \ln Sp$ | 0.80 |
| $\ln SCH = 3.05 + 0.29 \ln H$ | 0.69 |
| $SCH = 8.71 + 0.90\ H + 28.27\ Co + 0.33\ Sp$ | 0.74 |
| $SOTQ = 54.15 - 0.74\ H + 3.10\ Co + 2.47\ Sp$ | 0.55 |

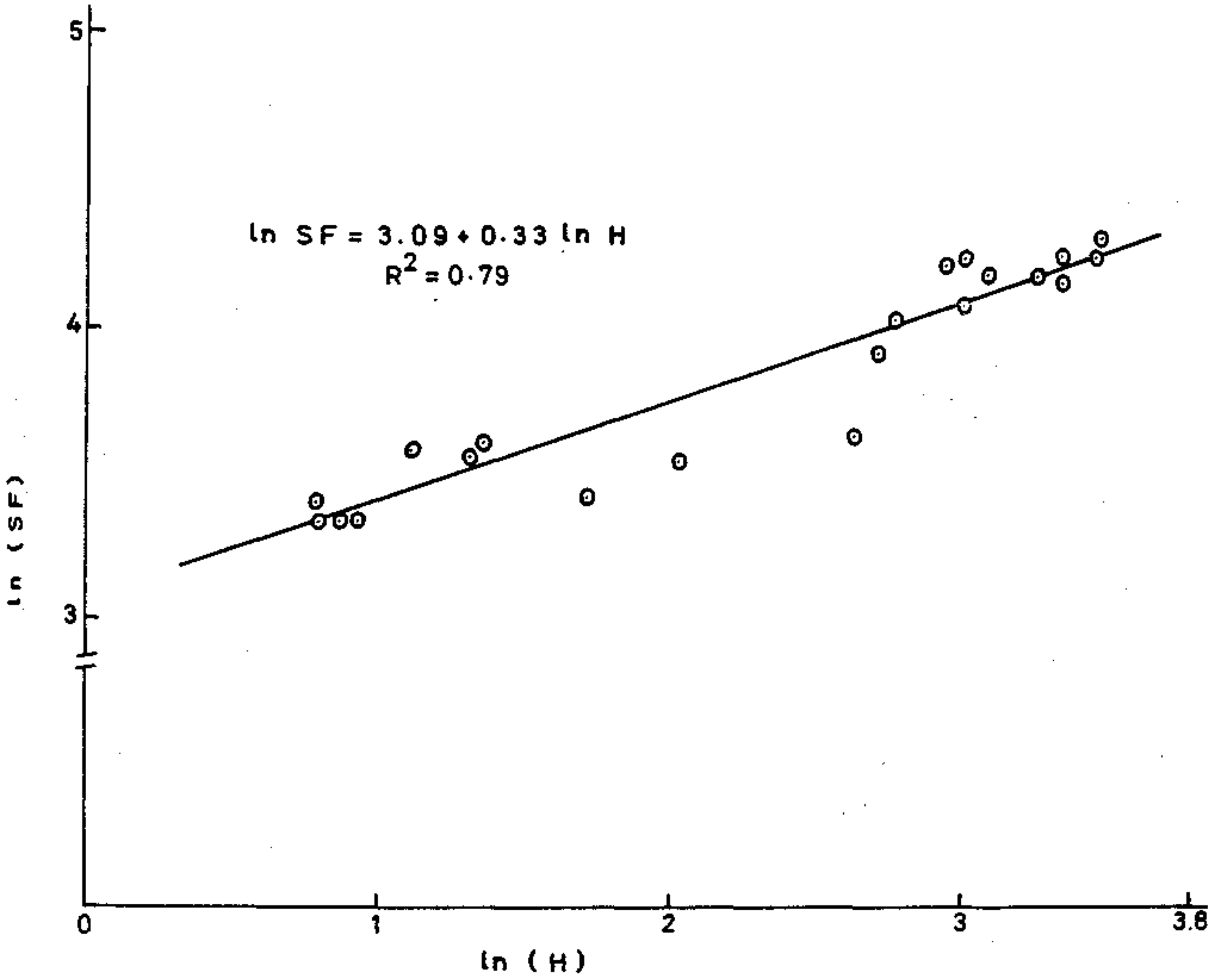


FIG.4.1 RELATIONSHIP BETWEEN SUBJECTIVE FIRMNESS (SF) AND OBJECTIVE HARDNESS ($H, mN/mm^2$) OF CHHANA

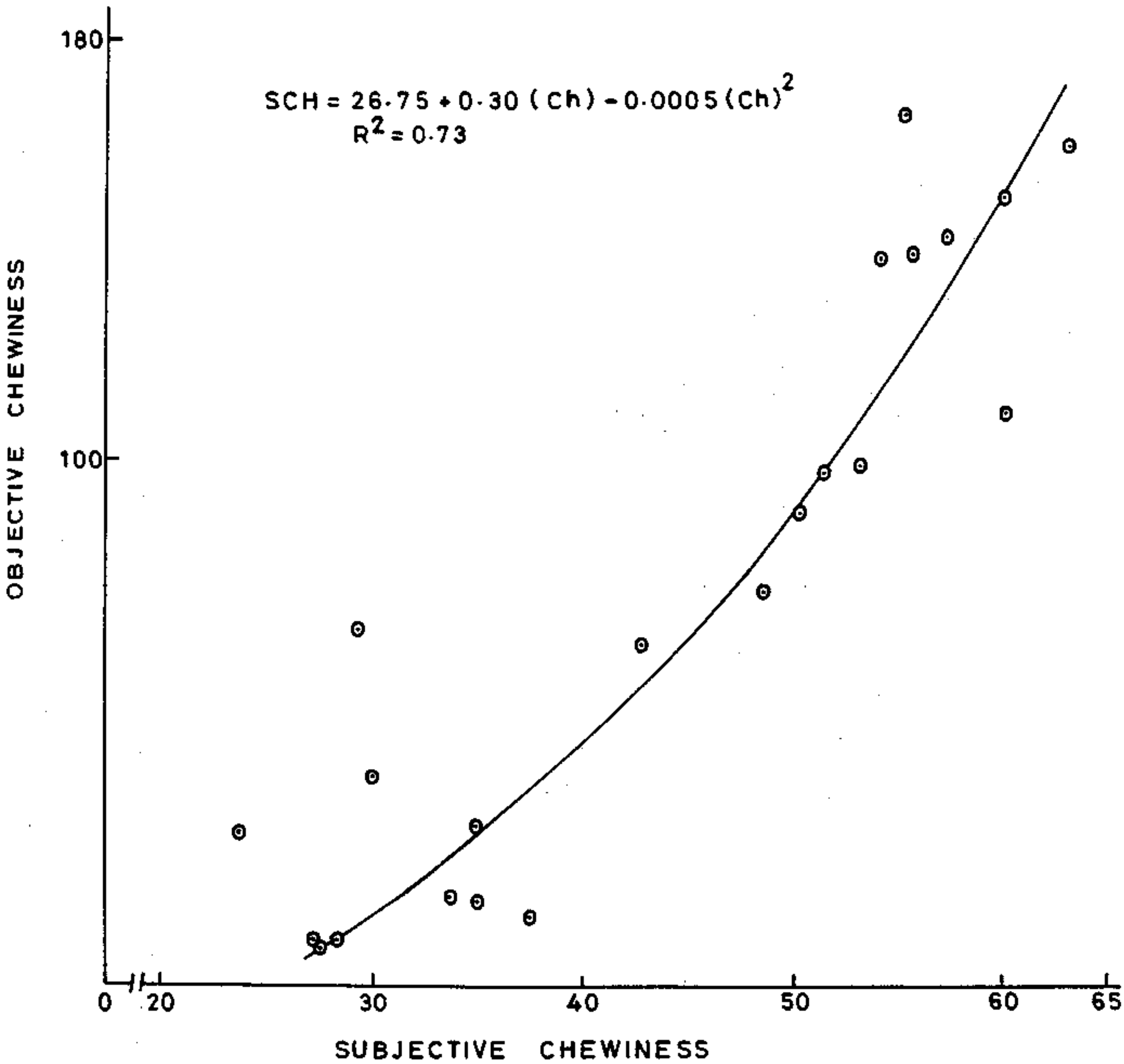


FIG.4.2 RELATIONSHIP BETWEEN SUBJECTIVE CHEWINESS (SCH) AND OBJECTIVE CHEWINESS (Ch, mN. mm) OF CHHANA

of chhana based on its composition. The simple correlation matrix obtained between Instron textural and compositional characteristics showed that instrumental textural measurements were significantly correlated with all chemical parameters including pH (except for springiness with pH) (Table 4.21). Moisture appeared to be the most important compositional factor, showing the highest coefficient for correlation closely followed by fat and protein contents. The calcium content and pH exhibited the smaller degree of correlation with the Instron parameters. Thus as the moisture content increased the values for hardness and other properties declined, but with the increasing fat, protein or calcium content, the values increased. Keller et al. (1974) observed significant correlation of calcium and moisture contents with rheological properties such as elasticity and viscosity of directly acidified mozzarella cheese.

Since moisture content showed highly significant ($P \angle 0.01$) correlation with other compositional characteristics especially fat and protein contents (Table 4.22), regression equations considering only one of these parameters, moisture, in particular, were developed (Table 4.23). It can be seen from these equations that the moisture alone could account for most (85%) of the variation in hardness of chhana (Fig. 4.3), fat and calcium being much less consequence (73 and 61%). However, multiple regression of hardness with moisture, calcium and pH was slightly better (87%) than that with moisture alone.

Table 4.21 Coefficients of correlation[a] (simple) between instrumental texture measurements and compositional parameters of chhana

| Attribute | Hardness (H) | Cohesiveness (Co) | Springiness (Sp) | Gumminess (Gu) | Chewiness (Ch) |
|---|---|---|---|---|---|
| Moisture, % (Mo) | -0.63** | -0.54** | -0.29** | -0.84** | -0.78** |
| Fat, % (F) | 0.61** | 0.53** | 0.28** | 0.81** | 0.75** |
| Fat in dry matter, % (FDM) | 0.63** | 0.48** | 0.23* | 0.63** | 0.58** |
| Protein, % (PR) | 0.75** | 0.50** | 0.28** | 0.75** | 0.70** |
| Protein in dry matter, % (PRDM) | -0.61** | -0.43** | -0.19* | -0.62** | -0.56** |
| Calcium, % (Ca) | 0.69** | 0.22* | 0.32** | 0.70** | 0.68** |
| pH | -0.30** | -0.20* | -0.13 | -0.29** | -0.28** |

[a] Based on 108 observations

* $P < 0.05$, ** $P < 0.01$

Table 4.22 Coefficients of correlation[a] (simple) among compositional parameters

| Attribute | Mo | F | FDM | PR | PRDM | Ca | pH |
|---|---|---|---|---|---|---|---|
| Moisture, % (Mo) | - | | | | | | |
| Fat, % (F) | -0.98** | - | | | | | |
| Fat in dry matter, % (FDM) | -0.83** | 0.92** | - | | | | |
| Protein, % (PR) | -0.92** | 0.83** | 0.57** | - | | | |
| Protein in dry matter, % (PRDM) | 0.77** | -0.87** | -0.97** | -0.47** | - | | |
| Calcium, % (Ca) | -0.51** | 0.46** | 0.29** | 0.49** | -0.31** | - | |
| pH | 0.39** | -0.33** | -0.17 | -0.49** | 0.10 | 0.08 | - |

[a] Based on 108 observations

* $P < 0.05$, ** $P < 0.01$

Table 4.23 Regression equations between instrumental texture measurements and compositional parameters of chhana

| Equation | $R^2$ |
|---|---|
| $\ln H = 32.74 - 7.47 \ln Mo$ | 0.85 |
| $\ln H = 2.63 \ln F - 5.43$ | 0.73 |
| $H = -126.86 + 451.45\, Ca - 311.91\, Ca^2$ | 0.61 |
| $H = 31.41 - 6.52 \ln Mo + 1.18 \ln Co - 0.95 \ln pH$ | 0.87 |

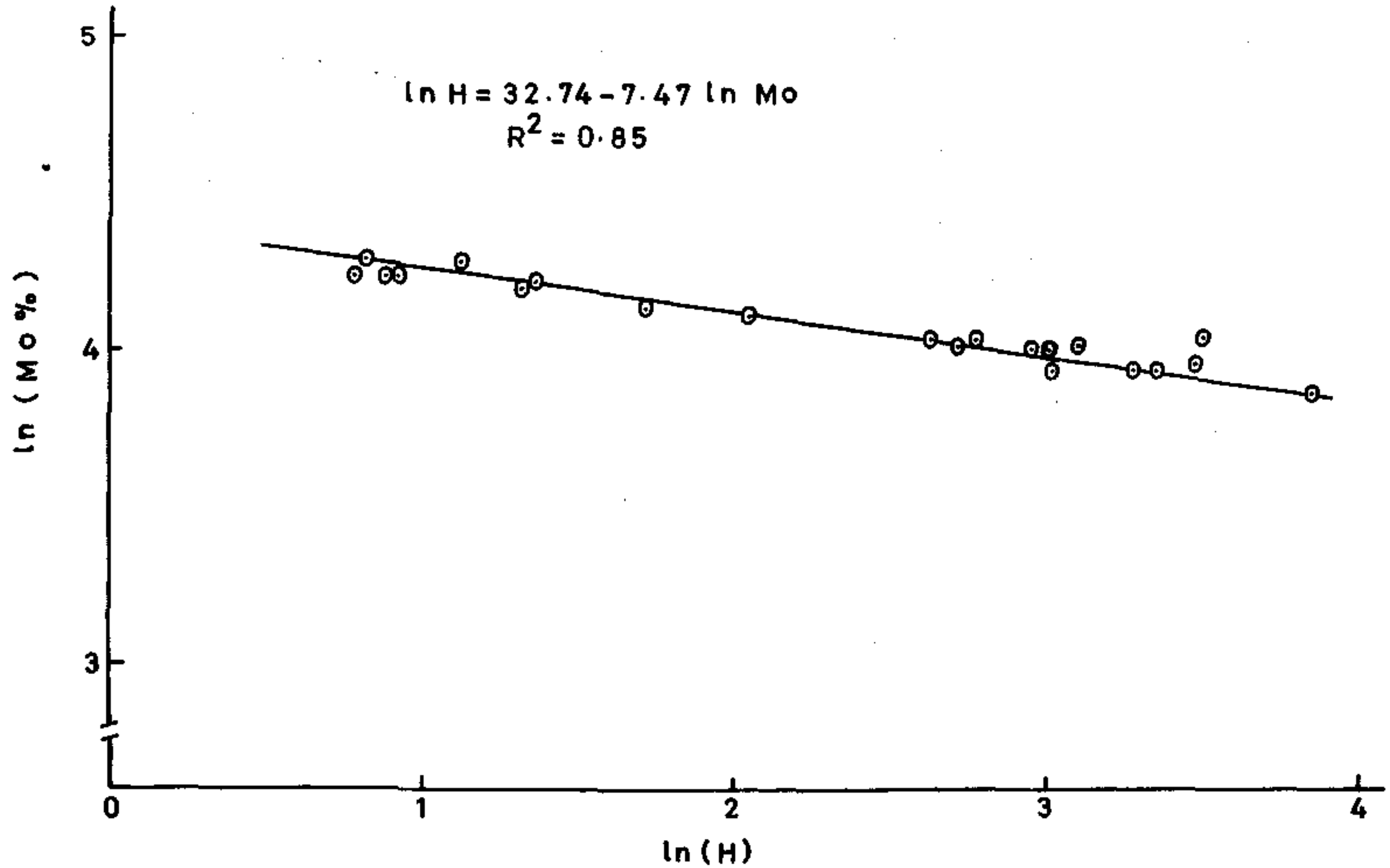


FIG. 4.3 RELATIONSHIP BETWEEN OBJECTIVE HARDNESS ($H$, $mN/mm^2$) AND MOISTURE CONTENT ($Mo$, PERCENT) OF CHHANA

4.1.6.3 Relationships between Sensory Textural Properties and Compositional Parameters of Chhana:

Texture being (by definition) a sensory property, moisture-fat characteristics have a definite role in sensory texture perception. Moisture and protein contents (Table 4.24) showed highly significant ($P < 0.01$) and almost equal correlations with all sensory attributes except crumbliness (for moisture alone). Fat content also appeared to be significantly correlated ($P < 0.01$) with most sensory measurements but to an appreciably lower extent than moisture and protein contents. Calcium and pH exhibited the least correlations. As moisture content and pH increased, sensory elasticity, firmness and chewiness tended to decrease whereas stickiness, smoothness and overall texture score tended to increase. The opposite was true with the protein and calcium contents (Table 4.24). These two compositional parameters seemed to be the largest determinants of the overall sensory textural score followed by fat and pH.

Simple and multiple regression analyses (Table 4.25) indicated that moisture alone could explain the variation in sensory elasticity and firmness of chhana to an appreciably greater extent than fat. Use of calcium and pH together with moisture as chemical parameters enhanced the predictability of elasticity only slightly but that of firmness considerably. Sensory stickiness and chewiness was also accounted appreciably by these three

Table 4.24 Coefficients of correlation[a] (simple) between sensory textural attributes and compositional parameters of chhana

| Attribute | SE | SF | SCR | SST | SSM | SCH | SOTQ |
|---|---|---|---|---|---|---|---|
| Mo | -0.61** | -0.66** | -0.18 | 0.76** | 0.47** | -0.76** | 0.51** |
| F | 0.77** | 0.80** | 0.13 | -0.72** | -0.40** | 0.69** | -0.43** |
| FDM | 0.61** | 0.59** | 0.00 | -0.52** | -0.20* | 0.46** | -0.20* |
| PR | 0.81** | 0.86** | 0.26** | -0.73** | -0.53** | 0.78** | -0.59** |
| PRDM | -0.54** | -0.54** | 0.03 | 0.50** | 0.17 | -0.42** | 0.18 |
| Ca | 0.49** | 0.60** | 0.14 | -0.43** | -0.54** | 0.62** | -0.59** |
| pH | -0.36** | -0.40** | -0.24* | 0.45** | 0.32** | -0.41** | 0.31** |

[a] Based on 108 observations

* $P < 0.05$, ** $P < 0.01$

Table 4.25 Regression equations between sensory textural attributes and compositional characteristics of chhana

| Equation | $R^2$ |
|---|---|
| SE = 145.14 - 1.58 Mo | 0.66 |
| SE = 11.23 + 2.03 F | 0.60 |
| SE = 169.28 - 1.37 Mo + 22.00 Ca - 8.01 pH | 0.68 |
| SF = 167.90 - 1.98 Mo | 0.74 |
| SF = 0.29 + 2.51 F | 0.65 |
| SF = 209.27 - 1.50 Mo + 55.45 Ca - 16.53 pH | 0.80 |
| SST = 1.19 Mo - 32.43 | 0.58 |
| SST = -95.61 + 0.94 Mo - 19.19 Ca + 14.94 pH | 0.62 |
| SCH = 187.79 - 0.84 Mo + 69.76 Ca - 21.78 pH | 0.70 |
| SOTQ = -29.85 + 0.22 Mo - 65.0 Ca + 18.66 pH | 0.43 |

parameters taken together. It is, however, noteworthy that although the chemical parameters could provide substantial information regarding individual sensory texture attributes, moisture, calcium and pH explained only 43% variation in the overall sensory texture score (Table 4.25).

4.1.6.4 Relationships among Instrumental Rheological Properties: A possible correlation among objective textural properties can lead to quantification of their interdependence. As shown in Table 4.26, the highly significant ($P < 0.01$) correlations between hardness and cohesiveness, and hardness and springiness indicate the structural properties of chhana determining that the hardness had considerable influence on cohesiveness and springiness. These correlations also imply that the factors leading to firming of the product also resulted in increased cohesiveness and springiness. However, the correlation coefficients were not high enough to permit adequate predictions. High correlations between hardness and gumminess, and hardness and chewiness were only expected since gumminess and chewiness are derived from hardness, cohesiveness and springiness which among themselves are significantly correlated. Relatively smaller, though significant, correlations between cohesiveness or springiness, and gumminess and chewiness, however, is indicative of the predominant role of hardness in deciding these latter properties. Thus instrumental hardness appear

Table 4.26 Coefficients of correlation[a] (simple) among rheological properties of chhana

| Attribute | Hardness (H) | Cohesiveness (Co) | Springiness (Sp) | Gumminess (Gu) | Chewiness (Ch) |
|---|---|---|---|---|---|
| H | - | | | | |
| Co | 0.42** | - | | | |
| Sp | 0.40** | 0.01 | - | | |
| Gu | 0.99** | 0.48** | 0.38** | - | |
| Ch | 0.98** | 0.39** | 0.52** | 0.97** | - |

[a] Based on 108 observations

* $P < 0.05$, ** $P < 0.01$

to be the single most important objective attribute of chhana.

4.1.6.5 Relationships among Sensory Textural Characteristics: This information can be of considerable help in minimizing the error in assessing sensory textural attributes if their dependence on each other could be so ascertained as to allow prediction of one or more properties from a limited number of relatively easily determined attributes. The relationships among subjective textural characteristics of chhana have been shown in Table 4.27 and the relevant regression equations in Table 4.28.

The complexity of sensory evaluation is evident from Table 4.27 which shows that all the sensory textural properties of chhana were associated directly or inversely with each other. Sensory elasticity showed high positive correlations ($P < 0.01$) with firmness, and chewiness and a negative correlation with stickiness. It also showed significant, though lower, direct relation with crumbliness ($P < 0.05$) and inverse relation with smoothness ($P < 0.01$). Firmness was closely related with stickiness, smoothness and chewiness besides elasticity, the relationship being negative with stickiness and smoothness and positive with chewiness. This indicated that the manufacturing conditions coupled with the resulting composition of the products causing the chhana to be firmer, made the product less sticky but coarser and more chewy. Among other interrelationships, those of chewiness with stickiness and smoothness, both negative, were prominent. Thus like instrumental

Table 4.27 Coefficients of correlation[a] (simple) among sensory textural characteristics of chhana

| Attribute | SE | SF | SCR | SST | SSM | SCH | SOTQ |
|---|---|---|---|---|---|---|---|
| Elasticity (SE) | - | | | | | | |
| Firmness (SF) | 0.78** | - | | | | | |
| Crumbliness (SCR) | 0.24* | 0.32** | - | | | | |
| Stickiness (SST) | -0.73** | -0.86** | -0.39** | - | | | |
| Smoothness (SSM) | -0.42** | -0.72** | -0.31** | 0.63** | - | | |
| Chewiness (SCH) | 0.72** | 0.92** | 0.43** | -0.82** | -0.76** | - | |
| Overall textural quality (SOTQ) | -0.48** | -0.77** | -0.39** | 0.69** | 0.89** | -0.82** | - |

[a] Based on 108 observations

* $P < 0.05$, ** $P < 0.01$

Table 4.28 Equations indicating interrelationships among individual sensory textural attributes of chhana

| Equation | $R^2$ |
|---|---|
| $\ln SE = 1.30 + 0.67 \ln SF$ | 0.67 |
| $\ln SST = 6.37 - 0.71 \ln SE$ | 0.50 |
| $SCH = 100.46 - 0.96\ SSM$ | 0.58 |
| $SCH = 82.59 - SST$ | 0.66 |
| $\ln SCH = 0.42 + 0.85 \ln SE$ | 0.54 |
| $\ln SCH = 0.42 + 0.85 \ln SF$ | 0.82 |
| $SOTQ = 86.31 - 0.51\ SF$ | 0.59 |
| $SOTQ = 8.38 + 0.89\ SSM$ | 0.79 |
| $SOTQ = 89.96 - 0.65\ SCH$ | 0.68 |
| $SOTQ = 36.20 + 0.08\ SE - 0.06\ SF - 0.06\ SCR + 0.05\ SST + 0.59\ SSM - 0.23\ SCH$ | 0.85 |

hardness (Table 4.26), sensory firmness appeared to be the most important of all attributes. Chewiness and to some extent smoothness were also equally significant as individual sensory properties, but had much greater influence on the overall textural quality (Table 4.27). Thus the overall sensory textural quality of chhana directly related to smoothness of the product and inversely with chewiness and firmness.

Regression equations presented in Table 4.28 show that logarithmically regressed sensory firmness of chhana could explain 67% and 82% variation in elasticity and chewiness, respectively (equation 1 and 6). With respect to the overall sensory textural quality of the product, smoothness was most predictive (79%) followed by chewiness (68%) and firmness (59%). However, the predictability of overall texture was greatly enhanced (85%) when all the individual sensory attributes were taken into account, in which also smoothness appeared to have most significant role to play (equation 10).

## 4.2 PANEER

### 4.2.1 Market Paneer

#### 4.2.1.1 Composition:

4.2.1.1.A Raw: Texture being a sensory property, compositional attributes such as moisture, fat etc. are expected to affect its perception. Chawla *et al.* (1985) observed that fat in paneer contributed to soft and spongy body of paneer.

The composition of market paneer, as observed in the present study, has been reported in Table 4.29. Moisture, fat, protein and ash contents varied from 50.97 to 57.95%, 20.13 to 24.9%, 16.68 to 19.74% and 1.49 to 1.97% respectively. Similar values were reported by Rajorhia et al. (1984) for market samples of paneer. The calcium and phosphorus contents of market paneer was found to vary from 0.52 to 0.74% and 0.23 to 0.34% respectively.

It is noteworthy that the supplier-wise variation in the composition was significant ($P < 0.01$). Also the fat content on dry matter basis was found to be lower than legally prescribed (50%) in samples MP-1 and MP-5. The pH of paneer from different suppliers was observed to be more or less the same the range being 5.72 to 5.97. The variations in the composition of market paneer are likely to be due to difference in the quality of milk used and method of manufacture employed.

4.2.1.1.B <u>Fried and Cooked Market Paneer</u>: For consumption as a culinary item, paneer is often fried and then cooked alongwith vegetables. Composition of fried and cooked paneer has not been reported so far hence not available in literature. The combined effect of deep fat frying and cooking in saline water on moisture, fat and protein contents of paneer has been shown in Table 4.30.

It can be visualized from the data that the moisture content increased considerably as a resulting

Table 4.29 Compositional characteristics of market paneer

| Constituent | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 | | |
| Moisture, % | 57.95 | 50.97 | 51.24 | 53.94 | 51.20 | 57.20 | 7.48** | 3.37 |
| Fat, % | 20.13 | 24.99 | 24.90 | 23.30 | 23.92 | 21.92 | 7.34** | 2.02 |
| Fat in dry matter, % | 47.86 | 50.97 | 51.05 | 50.39 | 48.78 | 51.19 | 15.36** | 1.04 |
| Protein, % | 17.50 | 20.14 | 19.74 | 18.75 | 20.41 | 16.68 | 9.00** | 1.47 |
| Protein in dry matter, % | 41.60 | 41.07 | 40.48 | 40.33 | 41.88 | 38.92 | 12.37** | 0.88 |
| Ash, % | 1.69 | 1.49 | 1.62 | 1.72 | 1.97 | 1.57 | 17.87** | 0.12 |
| Calcium, % | 0.65 | 0.53 | 0.52 | 0.66 | 0.74 | 0.57 | 13.39** | 0.07 |
| Phosphorus, % | 0.26 | 0.23 | 0.24 | 0.28 | 0.34 | 0.25 | 29.83** | 0.11 |
| pH of paneer | 5.76 | 5.81 | 5.72 | 5.81 | 5.73 | 5.97 | 2.13 | - |

Average of six replicates

[a] Refers to the Vendor/Supplier of paneer

* $P < 0.05$, ** $P < 0.01$

Table 4.30 Composition of fried and cooked market paneer

| Constituent | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | MPF1 | MPF2 | MPF3 | MPF4 | MPF5 | MPF6 | | |
| Moisture, % | 68.15 | 68.06 | 66.11 | 66.07 | 65.64 | 68.13 | 2.28 | - |
| Fat, % | 15.80 | 16.43 | 17.55 | 17.73 | 17.30 | 16.75 | 2.74* | 1.29 |
| Fat in dry matter, % | 49.36 | 51.46 | 51.81 | 52.25 | 50.30 | 52.29 | 8.96** | 1.21 |
| Protein, % | 13.30 | 13.00 | 13.64 | 13.48 | 14.22 | 12.13 | 4.03** | 1.02 |
| Protein in dry matter, % | 41.52 | 40.66 | 40.26 | 39.69 | 41.43 | 38.07 | 16.17** | 0.93 |
| % moisture of raw paneer | 117.76 | 133.60 | 129.15 | 122.67 | 129.01 | 118.32 | | |

Average of six replicates

[a] Refers to the Vendor/Supplier of paneer

* $P < 0.05$, ** $P < 0.01$

frying and cooking the increase ranging from 17.8 to 33.60%. The apparently reduced fat and protein contents could obviously be attributed to the corresponding increased moisture content. However, on dry matter basis there was a slight increase in the fat content and a slight decrease in the protein content, which might be due to oil absorption during frying. It is important to note that the supplier-wise difference in moisture content ($P < 0.01$) that existed in raw paneer disappeared upon frying and cooking, whereas the differences in the fat and protein contents persisted (Table 4.29) which indicated that the water-holding capacity of all paneer, when fried and then cooked, was presumably the same irrespective of the original moisture content.

4.2.1.2 Textural Properties:

4.2.1.2.A Raw Paneer: The desirable body of paneer is one that is neither too firm nor too soft. It should be sufficiently firm to hold its shape during cutting/slicing and yet tender enough not to resist crushing during mastication. The texture of high grade paneer should be compact (close-knit), smooth and velvety (Patil and Gupta, 1986). Kulshreshtha et al. (1987) stated that quality of paneer is judged on the basis of its cohesive strength, moisture content and sponginess.

The observations on sensory and instrumentally measured textural quality of market paneer (raw) have been presented in Table 4.31 and 4.32, respectively. It can be

Table 4.31 Sensory texture score (max.100) for market paneer

| Attribute | Sample[a] | | | | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|---|---|---|
| | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 | | |
| Elasticity | 61.11 | 60.28 | 58.42 | 57.32 | 61.01 | 51.87 | 3.25** | 3.13 |
| Firmness | 59.47 | 68.41 | 62.03 | 57.93 | 68.70 | 48.41 | 14.93** | 3.18 |
| Crumbliness | 45.24 | 40.39 | 46.01 | 47.99 | 46.58 | 46.01 | 1.34 | - |
| Stickiness | 24.55 | 22.71 | 25.33 | 25.70 | 20.39 | 30.35 | 5.05** | 2.72 |
| Smoothness | 49.23 | 51.10 | 49.90 | 51.66 | 42.33 | 56.15 | 3.83** | 3.66 |
| Chewiness | 53.49 | 62.70 | 56.02 | 52.49 | 59.66 | 45.07 | 6.25** | 3.94 |
| Overall textural quality | 62.25 | 66.23 | 58.56 | 63.68 | 55.24 | 64.57 | 5.21** | 2.93 |

Average of six replicates

[a] Refers to the Vendor/Supplier of paneer

[b] Based on arc-sine values vide Appendix VIII

* $P < 0.05$, ** $P < 0.01$

Table 4.32 Instron textural attributes of market paneer

| Attribute | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 | | |
| Hardness, mN | 22.64 | 31.27 | 30.81 | 25.13 | 36.39 | 15.89 | 7.86** | 7.52 |
| Cohesiveness | 0.66 | 0.67 | 0.68 | 0.67 | 0.68 | 0.67 | 0.29 | - |
| Springiness, mm | 8.13 | 8.71 | 8.04 | 8.04 | 8.83 | 8.17 | 1.68 | - |
| Gumminess, mN | 14.71 | 20.63 | 20.67 | 16.99 | 24.81 | 10.63 | 9.55** | 4.61 |
| Chewiness, mN.mm | 120.52 | 181.43 | 144.62 | 139.33 | 223.15 | 82.12 | 10.14** | 42.32 |

Average of six replicates

[a] Refers to the Vendor/Supplier of paneer

* P ∠ 0.05, ** P ∠ 0.01

seen that almost all the market samples of paneer were moderately elastic, firm, crumbly and chewy although all properties except crumbliness showed significant ($P < 0.01$) supplier-wise differences. On the basis of overall sensory textural quality MP-2 paneer was rated best presumably because of its firmness, low crumbliness and moderate smoothness. The significant differences observed in elasticity (F ratio, $4.65^{**}$), firmness ($6.20^{**}$), crumbliness ($3.83^{**}$), stickiness ($3.59^{**}$), smoothness ($6.31^{**}$), chewiness ($2.39^{*}$) and overall textural quality ($2.45^{*}$), among replications was indicative of the variability of paneer obtained from the same supplier. Instrumentally determined hardness and chewiness (Table 4.32) exhibited, in general, similar differences ($P < 0.01$) as observed in the sensory attributes, but springiness did not show any significant differences. Instron cohesiveness substantiated the sensory observation, the paneers from different suppliers were similar in this regard. The lower hardness of MP-1 and MP-6 paneers can be attributed to the higher moisture content of these samples. The treatest hardness of paneer MP-5 may be related to its highest calcium content (Table 4.29).

4.2.1.2.B <u>Fried and Cooked Market Paneer</u>: The textural properties of raw paneer appeared to undergo considerable changes upon frying and cooking as is evident from Tables 4.33 and 4.34. The sensory elasticity, crumbliness and chewiness generally showed appreciable increase, whereas smoothness and firmness exhibited appreciable decrease as

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* $P < 0.05$, ** $P < 0.01$

Table 4.33 Sensory textural characteristics (max.score, 100) of fried and cooked market paneer

| Attribute | Sample[a] | | | | | | F. ratio[b] | CD[b] |
|---|---|---|---|---|---|---|---|---|
| | MPF1 | MPF2 | MPF3 | MPF4 | MPF5 | MPF6 | | |
| Elasticity | 66.51 | 67.79 | 60.38 | 64.25 | 64.60 | 65.65 | 1.38 | - |
| Firmness | 53.98 | 52.30 | 58.72 | 55.07 | 63.33 | 43.51 | 13.65** | 2.89 |
| Crumbliness | 47.49 | 45.62 | 50.10 | 52.32 | 49.91 | 55.37 | 1.76 | - |
| Smoothness | 45.50 | 50.59 | 42.85 | 45.73 | 39.55 | 43.30 | 5.03** | 2.62 |
| Chewiness | 62.57 | 57.22 | 60.41 | 61.37 | 65.33 | 53.21 | 3.81** | 3.54 |
| Juiciness | 65.42 | 69.31 | 59.23 | 60.12 | 58.48 | 63.50 | 6.72** | 2.68 |
| Overall textural quality | 68.15 | 74.70 | 63.87 | 67.00 | 63.24 | 61.64 | 8.50** | 2.78 |

Average of six replicates

[a] Refers to the Vendors/Supplier of paneer

[b] Based on arc-sine values vide Appendix IX

* $P < 0.05$, ** $P < 0.01$

Table 4.34 Instrumental textural properties of fried and cooked market paneer

| Attribute | Sample[a] | | | | | | F.ratio | CD |
|---|---|---|---|---|---|---|---|---|
| | MPF1 | MPF2 | MPF3 | MPF4 | MPF5 | MPF6 | | |
| Hardness, mN | 12.19 | 10.19 | 12.21 | 10.40 | 13.87 | 6.25 | 8.03** | 2.63 |
| Cohesiveness | 0.75 | 0.72 | 0.73 | 0.72 | 0.73 | 0.74 | 0.99 | - |
| Springiness, mm | 10.63 | 9.92 | 10.04 | 9.67 | 10.38 | 8.83 | 2.53* | 1.07 |
| Gumminess, mN | 9.20 | 7.27 | 8.92 | 7.52 | 9.33 | 4.66 | 9.16** | 1.66 |
| Chewiness, mN.mm | 99.68 | 74.08 | 88.69 | 74.43 | 97.31 | 41.45 | 9.20** | 20.09 |

Average of six replicates

[a] Refers to the Vendor/Supplier of paneer

* $P < 0.05$, ** $P < 0.01$

a result of frying and cooking. However, stickiness remained more or less unaffected. Further, the shop-wise differences that were observed in elasticity and stickiness of raw paneer became non-significant. The overall textural quality differed significantly ($P < 0.01$) among suppliers as also observed for raw paneer. Also, MP-2 paneer was found to be the most desirable, the differences between it and other paneer samples being significant. However, the order in which among the other five paneer samples differed was altered as compared to raw paneer. The greatest value for elasticity together with significantly ($P < 0.01$) higher juiciness of MPF-2 paneer might be atleast partly responsible for its highest sensory acceptability. The generally enhanced sensory texture scores of fried and cooked paneer were in agreement with the improvement in the textural quality of paneer upon frying and cooking reported by Chawla _et al._ (1985) and Sachdeva and Singh (1988).

Among objective textural parameters also, hardness decreased and springiness increased in fried and cooked paneer, the decrease in hardness being much more remarkable (Table 4.34) as compared to the increase in (sensory elasticity) springiness. Corresponding to sensory crumbliness, Instron cohesiveness of fried and cooked paneer registered perceivable increase. However, a reverse effect was noticed in chewiness which was considerably decreased, thereby indicating the difference in the mechanism of sensory perception and instrumental measurement of this attribute. Besides hardness, gumminess and chewiness, springiness of fried and cooked paneer was also found to vary significantly ($P < 0.01$) among suppliers, cohesiveness showing non-significant variation.

4.2.2 Buffalo Milk Paneer

The results on composition as well as instrumental and sensory textural measurements of laboratory made, raw, and fried and cooked paneer obtained from buffalo milk have been discussed in this section.

4.2.2.1 Composition:

4.2.2.1.A Raw Paneer: The composition of paneer prepared from standardized (6% fat) buffalo milk using three different methods (Fig. 3.4) has been shown in Table 4.35. It can be seen that while the moisture content was lower, fat was higher in comparison to market paneer (Table 4.29). The protein content was however, similar to that of the market paneer. On dry matter basis, the fat content was well above the legally required minimum. Methodwise, RBP paneer showed a significantly ($P < 0.05$) higher protein content than in the other two paneer samples, the remaining chemical parameters being non-significantly different in this regard.

4.2.2.1.B Fried and Cooked Buffalo Milk Paneer: The moisture, fat and protein contents of fried and cooked buffalo milk paneer has been depicted in Table 4.36. As

Table 4.35 Composition of buffalo milk paneer

| Constituent | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | SBP | BBP | RBP | | |
| Moisture, % | 47.77 | 47.83 | 46.51 | 1.23 | - |
| Fat, % | 29.09 | 29.20 | 29.25 | 0.04 | - |
| Fat in dry matter, % | 55.70 | 55.98 | 54.67 | 11.52** | 0.61 |
| Protein, % | 19.12 | 18.99 | 20.09 | 4.94* | 0.82 |
| Protein in dry matter, % | 36.60 | 36.39 | 37.55 | 13.45** | 0.51 |
| Ash, % | 1.83 | 1.81 | 1.84 | 0.28 | - |
| Calcium, % | 0.69 | 0.68 | 0.65 | 3.62 | - |
| Phosphorus, % | 0.32 | 0.32 | 0.32 | 0.71 | - |
| pH of paneer | 5.86 | 5.87 | 5.92 | 2.62 | - |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.4

* P ∠ 0.05, ** P ∠ 0.01

Table 4.36 Composition of fried and cooked buffalo milk paneer

| Constituent | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | SBPF | BBPF | RBPF | | |
| Moisture, % | 68.18 | 68.38 | 68.33 | 0.07 | - |
| Fat, % | 17.45 | 17.43 | 17.16 | 0.43 | - |
| Fat in dry matter, % | 54.85 | 55.13 | 54.18 | 5.82* | 0.62 |
| Protein, % | 11.40 | 11.32 | 11.68 | 1.37 | - |
| Protein in dry matter,% | 35.83 | 35.77 | 36.88 | 9.07** | 0.63 |
| % moisture of raw paneer | 141.91 | 143.33 | 147.77 | | |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.4

* $P < 0.05$, ** $P < 0.01$

seen from table, there were no significant compositional differences due to methods. However, as in the case of market paneer, appreciable increase in moisture and simultaneous decline in fat and protein contents were noticeable as a result of frying and cooking, although on dry matter basis, the fat and protein contents remained more or less unaltered. It is interesting to note that the moisture content of fried and cooked buffalo milk paneer was almost same as that observed for similarly treated market paneer in spite of the differences in the moisture contents of raw paneer. This again substantiated that the water holding capacity of fried and cooked paneer remained almost unchanged in spite of variations in protein content of raw paneer (market paneer, 39-42% as against buffalo milk paneer, 36-38%, on dry matter basis).

4.2.2.2 Textural Properties:

4.2.2.2.A <u>Raw Paneer</u>: The data on the subjective and objective textural properties of raw buffalo milk paneer have been given in Table 4.37 and 4.38, respectively. It can be observed that as compared to SBP and RBP, BBP paneer had a significantly lower ($P \angle 0.01$) firmness, other sensory attributes including overall textural quality being alike for all types of paneer. Very little difference was observed between the sensory textural attributes of buffalo milk raw paneer and market raw paneer, except for smoothness which was more in the laboratory made paneer, contributing to its higher overall textural quality score.

As revealed from Table 4.38 all Instron parameters except cohesiveness, significantly differed among the types

Table 37: Sensory textural properties (max.score, 100) of buffalo milk paneer

| Attribute | Sample[a] | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|
| | SBP | BBP | RBP | | |
| Elasticity | 61.99 | 62.37 | 63.38 | 0.45 | - |
| Firmness | 65.25 | 57.30 | 64.30 | 9.41** | 2.25 |
| Crumbliness | 39.35 | 42.99 | 38.16 | 1.10 | - |
| Stickiness | 17.05 | 16.03 | 15.10 | 0.86 | - |
| Smoothness | 62.15 | 62.91 | 62.01 | 0.09 | - |
| Chewiness | 53.75 | 51.61 | 55.87 | 1.34 | - |
| Overall textural quality | 72.22 | 72.75 | 72.73 | 0.05 | - |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.4

[b] Based on arc-sine values vide Appendix X

* $P < 0.05$, ** $P < 0.01$

Table 4.38 Instron-texture profile analysis for buffalo milk paneer

| Attribute | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | SBP | BBP | RBP | | |
| Hardness, mN | 40.72 | 33.18 | 43.39 | 6.95** | 5.75 |
| Cohesiveness | 0.64 | 0.65 | 0.63 | 2.58 | - |
| Springiness, mm | 7.70 | 6.95 | 7.22 | 4.33** | 0.52 |
| Gumminess, mN | 25.19 | 21.17 | 26.59 | 8.99** | 2.69 |
| Chewiness, mN.mm | 206.36 | 151.95 | 199.85 | 8.63** | 28.93 |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.4

* $P < 0.05$, ** $P < 0.01$

of buffalo milk paneer. More precisely, these objective textural parameters showed lower values for BBP than for SBP and RBP. Since only the difference in hardness was sensorily perceived, differences in the other parameters were presumably not within limits of sensory perception.

4.2.2.2.B Fried and Cooked Buffalo Milk Paneer: It can be noticed from Tables 4.39 and 4.40 that the differences in subjective and objective textural attributes of fried and cooked paneer made by different methods were much narrower as compared to the differences observed in the case of raw paneer. All sensory parameters and all instrumental measurements except cohesiveness did not differ significantly.

In comparison to raw paneer, fried and cooked paneer was found to be more elastic and chewy, but not as firm or smooth. These observations were substantiated by instrumental analysis; hardness of fried and cooked paneer was markedly lower and higher springiness. However, objective measurement and sensory perception of chewiness showed opposite effects of frying and cooking, as also noted for market paneer (vide 4.2.1.2).

It can thus be inferred that with respect to the texture of fried and cooked paneer, methods SBP, BBP and RBP could be regarded more or less same, although certain textural differences were noticeable in these paneers before they were fried and cooked (i.e. raw). Similar observations were also made by Chawla *et al*. (1985) and

Table 4.39 Sensory textural properties (max.score, 100) of fried and cooked buffalo milk paneer

| Attribute | Sample[a] | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|
| | SBPF | BBPF | RBPF | | |
| Elasticity | 68.06 | 70.31 | 72.12 | 2.29 | - |
| Firmness | 45.42 | 44.93 | 45.85 | 0.09 | - |
| Crumbliness | 44.01 | 42.25 | 42.23 | 0.29 | - |
| Smoothness | 50.17 | 47.45 | 47.63 | 0.93 | - |
| Juiciness | 65.90 | 68.36 | 69.84 | 2.47 | - |
| Chewiness | 59.01 | 63.48 | 62.17 | 2.34 | - |
| Overall textural quality | 71.57 | 71.79 | 70.45 | 0.30 | - |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.4

[b] Based on arc-sine values vide Appendix XI

Table 4.40 Instron textural attributes of fried and cooked buffalo milk paneer

| Attribute | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | SBPF | BBPF | RBPF | | |
| Hardness, mN | 9.31 | 7.67 | 7.11 | 2.00 | - |
| Cohesiveness | 0.70 | 0.70 | 0.67 | 4.81* | 0.02 |
| Springiness, mm | 9.59 | 10.00 | 9.31 | 1.86 | - |
| Gumminess, mN | 6.46 | 5.30 | 4.77 | 2.64 | - |
| Chewiness, mN.mm | 63.32 | 53.03 | 44.42 | 2.96 | - |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.4

* $p < 0.05$

Sachdeva and Singh (1988) in relation to overall sensory textural quality of paneer.

### 4.2.3 Cow Milk and Low Fat Buffalo Milk Paneer

According to modified manufacturing methods, paneer of satisfactory quality from cow milk can be effected by employing higher coagulation temperature or by adding calcium chloride to milk prior to coagulation (Sachdeva et al., 1985). Paneer has also been prepared from low-fat (3.5%) fat buffalo milk (Chawla, 1981) and compositionally such a low fat product would be similar to cow milk paneer. Results on the composition and textural properties of paneer made from cow milk (SCCP and SCP) and low fat buffalo milk (CLFP) have been discussed in this section.

#### 4.2.3.1 Composition:

4.2.3.1.A Raw Paneer: The chemical composition of paneer SCCP, CLFP and SCP has been shown in Table 4.41. It is evident from the table that the moisture content of these paneers was more or less similar. However, the fat content of CLFP was significantly lower ($P < 0.01$) than that of SCCP or SCP. The protein content of SCCP was slightly but significantly ($P < 0.05$) lower than that of CLFP which was the highest but not significantly different from the protein content of SCP. The ash, calcium and phosphorus contents of the buffalo milk product (CLFP) were generally higher as compared to SCCP and SCP.

Table 4.41 Composition of cow milk and low fat buffalo milk paneer

| Constituent | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | SCCP | CLFP | SCP | | |
| Moisture, % | 51.23 | 52.04 | 50.28 | 2.94 | - |
| Fat, % | 23.93 | 21.18 | 24.67 | 53.99** | 0.76 |
| Fat in dry matter, % | 49.06 | 44.15 | 49.61 | 330.70** | 0.50 |
| Protein, % | 20.65 | 21.98 | 21.17 | 5.71* | 0.85 |
| Protein in dry matter, % | 42.35 | 45.80 | 42.57 | 72.96** | 0.69 |
| Ash, % | 1.89 | 2.04 | 1.71 | 12.08 | 0.15 |
| Calcium, % | 0.75 | 0.81 | 0.52 | 64.71** | 0.06 |
| Phosphorus, % | 0.30 | 0.34 | 0.28 | 11.02** | 0.03 |
| pH of paneer | 5.93 | 5.84 | 5.90 | 12.00** | 0.04 |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.6

* P ∠ 0.05, ** P ∠ 0.01

It should be noted that addition of calcium chloride at the rate of 1g/litre of milk caused coagulation of the milk many a times before it reached the final heating temperature (90$^{o}$C).

Thus while the modified coagulation processes of SCCP and SCP could effectively bring the moisture content of the resulting paneer close to the buffalo milk product. However, other compositional differences might be attributed to variation in the composition of milks used and to the use of calcium chloride for SCCP unlike for SCP.

4.2.3.1.8 <u>Fried and Cooked Cow Milk and Low Fat Buffalo Milk Paneers</u>: The effects of frying and subsequent cooking of paneer made from cow or low fat buffalo milks on the moisture content was nearly same as the one observed for market paneer and laboratory made buffalo milk paneer (Table 4.42). The final moisture content was in the usual range of 65-68%, SCP showing slightly but significantly lower ($P < 0.01$) value than SCCP or CLFP. The slight increase in fat content and decrease in protein content (on dry matter basis) as compared to the raw paneer was similar to the observation made in market paneer, whose fat content was also similar (48-51%, vide Table 4.29), as against a distinctly higher fat content of the buffalo milk paneer (55-56% vide Table 4.35) showing no perceivable influence of frying and cooking on the fat and protein contents. It thus appeared that when paneer had a fat content of about 50%, irrespective

Table 4.42 Composition of fried and cooked cow milk and low fat buffalo milk paneer

| Constituent | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | SCCPF | CLFPF | SCPF | | |
| Moisture, % | 67.60 | 67.15 | 65.19 | 6.47** | 1.53 |
| Fat, % | 16.81 | 15.31 | 18.20 | 22.77** | 0.92 |
| Fat in dry matter, % | 51.37 | 46.58 | 52.26 | 143.91** | 0.80 |
| Protein, % | 13.50 | 14.34 | 14.64 | 11.95** | 0.64 |
| Protein in dry matter, % | 41.67 | 45.18 | 42.08 | 63.36** | 0.73 |
| % moisture of raw paneer | 129.78 | 128.99 | 129.73 | | |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.5

* P $\angle$ 0.05, ** P $\angle$ 0.01

of the type of milk used, it tended to take up (i.e. absorb) fat/oil during deep-fat frying resulting in an increase in fat in dry matter (FDM), whereas with a higher fat content i.e. around 55%, it presumably tended to lose some fat while absorbing some oil during deep-fat frying with the net result that there was no perceptible change in FDM. Bhattacharya et al. (1971) also made similar observations.

Regarding the effect of method of manufacture, all three methods resulting in significantly ($P < 0.01$) different fat content in the fried and cooked paneer (Table 4.42), CLFP showing the lower value and SCP the highest. The protein contents of CLFP and SCP were similar but significantly higher ($P < 0.01$) than that of SCCP.

4.2.3.2 Textural Properties:

4.2.3.2.A Raw Paneer: The subjective and rheological properties of cow milk paneer (SCCP and SCP) and low fat buffalo milk (CLFP) paneer have been presented in Tables 4.43 and 4.44, respectively. SCCP paneer was found to be equally elastic, firm and chewy but more crumbly and less smooth as compared to SCP. Thus due to crumbliness and coarseness, it was rated significantly ($P < 0.01$) less desirable than both SCP and CLFP from the overall sensory texture point of view. The significant difference between latter two paneers may be associated with the difference in their elasticity, firmness and chewiness, CLFP with its higher values for these parameters being rather lower.

Table 4.43 Sensory textural assessment (max.score, 100) of cow milk and cow fat buffalo milk paneer

| Attribute | Sample[a] | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|
| | SCCP | CLFP | SCP | | |
| Elasticity | 57.75 | 66.81 | 57.44 | 7.42** | 3.24 |
| Firmness | 58.41 | 71.81 | 55.64 | 35.91** | 3.43 |
| Crumbliness | 63.28 | 45.62 | 46.96 | 16.91** | 3.87 |
| Stickiness | 22.59 | 18.52 | 28.66 | 10.47** | 2.99 |
| Smoothness | 48.83 | 49.70 | 63.13 | 19.92** | 2.91 |
| Chewiness | 56.37 | 68.65 | 52.91 | 13.91** | 3.63 |
| Overall textural quality | 60.45 | 67.44 | 71.29 | 17.19** | 2.24 |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.5

[b] Based on arc-sine values vide Appendix XII

* $P < 0.05$, ** $P < 0.01$

Table 4.44 Instrumental textural properties of cow milk and low fat buffalo milk paneer

| Attribute | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | SCCP | CLFP | SCP | | |
| Hardness, mN | 25.59 | 34.12 | 21.43 | 19.21** | 4.22 |
| Cohesiveness | 0.67 | 0.71 | 0.66 | 19.23** | 0.02 |
| Springiness, mm | 7.50 | 7.56 | 6.97 | 7.87** | 0.33 |
| Gumminess, mN | 17.04 | 24.31 | 14.12 | 25.33** | 2.98 |
| Chewiness, mN.mm | 131.27 | 185.49 | 99.58 | 23.94** | 25.40 |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.5

* P ∠ 0.05, ** P ∠ 0.01

Method-wise variations in the sensory textural attributes were also reflected in the instrumental parameter particularly hardness and springiness, CLFP being significantly harder ($P < 0.01$) than both SCCP and SCP, and more springy than SCP (Table 4.44). Also, CLFP was more cohesive ($P < 0.01$) than the other two products. Gumminess and chewiness showed similar trends as hardness.

4.2.3.2.8 <u>Fried and Cooked Cow Milk and Low Fat Buffalo Milk Paneer:</u> The textural differences among SCCP, CLFP and SCP paneer were considerably reduced upon frying and cooking as determined objectively and sensorily (Tables 4.45 and 4.46).

Method-wise variation ($P < 0.01$) persisted only in sensory firmness, smoothness and chewiness, and in a none of the Instron parameters. The highest overall sensory texture score for SCP was significantly higher than that for SCCP but similar to that for CLFP. Thus the relative rating of the three type of paneer remained unchanged after frying and cooking. CLFP paneer was found to be more elastic, firm, chewy and less smooth attributing to low overall textural quality score compared to buffalo milk (6% fat) paneer (vide Table 4.37).

## 4.2.4 Comparison between Market Paneer and Laboratory made Paneer

In order to elucidate the textural differences, if any, between market paneer and laboratory paneer, the market paneer found to be most acceptable with respect to

Table 4.45 Sensory textural properties (max.score, 100) of fried and cooked cow milk and low fat buffalo milk paneer

| Attribute | Sample[a] | | | F.ratio[b] | CD[b] |
|---|---|---|---|---|---|
| | SCCPF | CLPPF | SCPF | | |
| Elasticity | 67.64 | 68.21 | 66.79 | 0.33 | - |
| Firmness | 43.73 | 51.15 | 44.86 | 7.72** | 2.31 |
| Crumbliness | 47.10 | 42.20 | 45.10 | 2.51 | - |
| Smoothness | 43.53 | 42.25 | 48.41 | 6.07 | 2.13 |
| Juiciness | 61.50 | 57.67 | 60.29 | 1.82 | - |
| Chewiness | 62.70 | 71.45 | 60.62 | 29.70** | 1.89 |
| Overall textural quality | 62.47 | 65.45 | 62.82 | 4.80** | 2.06 |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.5

[b] Based on arc-sine values vide Appendix XIII

* $p < 0.05$, ** $p < 0.01$

Table 4.46 Instrumental textural properties of fried and cooked cow milk as well as low fat buffalo milk paneer

| Attribute | Sample[a] | | | F.ratio | CD |
|---|---|---|---|---|---|
| | SCCPF | CLFPF | SCPF | | |
| Hardness, mN | 8.66 | 9.36 | 9.35 | 0.35 | - |
| Cohesiveness | 0.70 | 0.66 | 0.65 | 2.07 | - |
| Springiness, mm | 9.38 | 0.56 | 8.75 | 2.31 | - |
| Gumminess, mN | 6.12 | 5.97 | 6.12 | 0.04 | - |
| Chewiness, mN.mm | 54.30 | 56.62 | 53.84 | 0.12 | - |

Average of eight replicates

[a] Refers to the method of manufacture vide Fig. 3.5

overall textural quality (considering both raw and fried and cooked paneer)was selected for comparison. The composition and subjective as well as objective textural properties of buffalo milk paneer and cow milk and low fat buffalo milk paneer were compared in two separate groups.

It can be seen from Table 4.31 that market paneer MP-2 was rated to be desirably firm, elastic and chewy, and moderately crumbly in addition to being fairly smooth. Thus its overall textural quality was rated best among all the market samples. Similarly even when fried and cooked this paneer was found to be the most acceptable (Table 4.37) and hence, it (MP-2 and MPF-2) was considered appropriate market product required for relative assessment of laboratory made paneer.

4.2.4.1 Buffalo Milk Paneer Vs Market Paneer:

4.2.4.1.1 Composition: The average moisture, fat and protein contents (on dry basis) of raw as well as fried and cooked paneer MP-2, SBP, BBP and RBP have been presented in Table 4.47. Fat contents (FDM) of laboratory paneer was significantly ($P < 0.01$) higher than that of market paneer, while the protein content (on dry basis) significantly ($P < 0.01$) lower in SBP, BBP and RBP as compared to MP-2. This could obviously be attributed to quality of milk used in relation to its fat and SNF contents.

Table 4.47 Effects of frying and cooking on moisture, fat and protein (on dry basis) of market as well as buffalo milk paneer

| Constituent | MP2 | | SBP | | BBP | | RBP | | Methods F.ratio (CD) | Frying F.ratio (CD) |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | FC | R | FC | R | FC | R | FC | | |
| Moisture, % | 50.97 | 68.06 | 48.51 | 68.71 | 49.01 | 68.84 | 47.99 | 68.37 | 1.41 (-) | 1685.07** (0.96) |
| Fat in dry matter, % | 50.97 | 51.46 | 55.75 | 54.92 | 56.11 | 55.20 | 54.57 | 54.05 | 95.90** (0.59) | 4.55* (0.42) |
| Protein in dry matter, % | 41.07 | 40.67 | 36.57 | 35.76 | 36.25 | 35.60 | 37.57 | 36.84 | 207.81** (0.46) | 16.68** (0.32) |

Average of six replicates (selected randomly from total 8 for SBP, BBP and RBP vide Tables 4.35 and 4.36

* $P < 0.05$ , ** $P < 0.01$

It is further revealed that frying and cooking processes significantly ($P < 0.01$) increased the moisture content, but slightly, though, significantly decreased fat ($P < 0.05$) and protein ($P < 0.01$) contents. It has been discussed earlier (vide 4.2.3.1.B) that such changes followed definite but different trends in paneer containing about 50% fat and that having a higher fat content.

4.2.4.1.2 **Texture of Market Paneer Vs Buffalo Milk Paneer:** The results on sensory textural properties (Table 4.48) of market paneer as compared to buffalo milk paneer (SBP, BBP and RBP) revealed that market paneer was significantly ($P < 0.01$) harder, more sticky and less smooth. However, elasticity, crumbliness, juiciness and overall textural quality of these products did not differ significantly. Further, it was noticed that frying and cooking significantly ($P < 0.01$) enhanced the elasticity and chewiness of paneer, but decreased the firmness and smoothness. Further, it is important to note that with respect to the overall sensory textural quality, neither the difference between market paneer and buffalo milk paneer was significant nor the effect of frying and cooking (Table 4.48). Thus slight differences noted in the raw paneer texture disappeared upon frying and cooking.

A comparison of objective textural attributes (Table 4.49) revealed that hardness, gumminess and chewiness of market and laboratory made paneer were similar.

Table 4.48 Comparison of sensory textural properties (max.score, 100) between raw and fried and cooked, market as well as buffalo milk paneer

| Attribute | MP2 | | SBP | | BBP | | RBP | | Methods | Frying |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | FC | R | FC | R | FC | R | FC | F.ratio[b] (CD) | F.ratio[b] (CD) |
| Elasticity | 60.28 | 67.79 | 62.36 | 67.36 | 60.54 | 70.56 | 63.33 | 71.59 | 1.36 (-) | 32.13** (1.55) |
| Firmness | 68.41 | 52.30 | 63.09 | 43.63 | 53.97 | 43.08 | 61.82 | 44.62 | 14.54** (2.07) | 152.52** (1.46) |
| Crumbliness | 40.39 | 45.62 | 39.58 | 44.01 | 42.79 | 40.29 | 36.91 | 41.67 | 0.86 (-) | 3.18 (-) |
| Stickiness | 22.71 | - | 17.78 | - | 16.54 | - | 15.98 | - | 4.69** (2.89) | - |
| Smoothness | 51.10 | 50.59 | 61.29 | 50.45 | 63.51 | 46.30 | 62.98 | 47.16 | 2.69* (2.21) | 65.58** (1.57) |
| Chewiness | 62.70 | 57.22 | 51.64 | 56.98 | 48.73 | 63.41 | 53.02 | 61.47 | 2.09 (-) | 12.15** (1.67) |
| Juiciness | - | 69.31 | - | 67.51 | - | 68.58 | - | 69.96 | - (-) | 2.07 (-) |
| Overall textural quality | 66.23 | 74.70 | 71.81 | 71.71 | 73.25 | 70.65 | 74.21 | 69.46 | 0.37 (-) | 0.05 (-) |

Average of six replicates (selected randomly from total 8 for SBP, BBP and RBP vide Tables 4.37 and 4.39)

[b] Based on arc-sine values vide Appendix XIV

* $P < 0.05$, ** $P < 0.01$

Table 4.49 Comparison of Instron textural properties of raw and fried and cooked paneer from market and buffalo milk

| Attribute | MP-2 | | SBP | | BBP | | RBP | | Methods | Frying |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | FC | R | FC | R | FC | R | FC | F.ratio (CD) | F.ratio (CD) |
| Hardness, mN | 31.27 | 10.19 | 27.46 | 7.07 | 24.69 | 6.84 | 33.39 | 6.48 | 0.94 (-) | 81.37** (4.85) |
| Cohesiveness | 0.67 | 0.72 | 0.66 | 0.71 | 0.66 | 0.70 | 0.64 | 0.68 | 3.87* (0.03) | 41.62** (0.02) |
| Springiness, mm | 8.71 | 9.92 | 7.19 | 9.58 | 6.77 | 9.88 | 6.96 | 9.08 | 2.96* (0.93) | 46.32** (0.66) |
| Gumminess, mN | 20.63 | 7.27 | 18.33 | 5.01 | 16.32 | 4.80 | 20.78 | 4.42 | 0.99 (-) | 89.29** (2.93) |
| Chewiness, mN.mm | 181.43 | 74.08 | 135.78 | 48.70 | 112.89 | 47.23 | 148.94 | 40.61 | 2.37 (-) | 48.29** (26.91) |

Average of six replicates (selected randomly from total 8 for SBP, BBP and RBP vide Tables 4.38 and 4.40)

* $P < 0.05$, ** $P < 0.01$

Cohesiveness and springiness however, were observed to be more in market paneer. Cohesiveness and springiness of paneer have been reported by Kulshreshtha et al. (1987) to be related to pressing conditions during paneer making. Thus, such differences between market and laboratory made paneer could be attributed to different pressing conditions.

Frying and cooking significantly reduced the hardness, gumminess and chewiness and increased the cohesiveness and springiness of the product. This could be attributed to structural changes in paneer upon frying and cooking. Kalab et al. (1988) observed that raw paneer had a granular structure consisting of protein particles having a core-and-lining ultrastructure which was compacted upon deep frying and partially restored upon cooking in saline water.

4.2.4.2 Market Paneer vs Cow Milk and Low Fat Buffalo Milk Paneer:

4.2.4.2.1 Composition: The data presented in Table 4.50 indicate that the moisture content of SCCP, CLFP and SCP paneer was similar to that of MP-2, although the moisture content of CP1 and LFP was significantly higher ($P < 0.01$) than that of CP3. The fat content (on dry basis) of SCCP and CLFP was significantly ($P < 0.01$) lower to that of market paneer, whereas of SCP had a similar fat content. The fat content-on-dry matter of all paneer samples was

Table 4.50 Effects of frying and cooking on major compositional attributes of market as well as cow and low fat buffalo milk paneer

| Constituent | MP2 | | SCCP | | CLFP | | SCP | | Methods | Frying |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | FC | R | FC | R | FC | R | FC | F.ratio (CD) | F.ratio (CD) |
| Moisture, % | 50.97 | 68.06 | 52.07 | 68.27 | 52.86 | 67.37 | 50.94 | 65.32 | 3.42* (1.48) | 916.08** (1.04) |
| Fat in dry matter, % | 50.97 | 51.46 | 49.00 | 51.85 | 44.19 | 46.67 | 49.59 | 52.24 | 137.47** (0.67) | 82.75** (0.47) |
| Protein in dry matter,% | 41.07 | 40.67 | 42.41 | 41.71 | 45.71 | 45.07 | 42.54 | 42.06 | 135.92** (0.48) | 11.18** (0.34) |

Average of six replicates (selected randomly from total 8 for SCCP, CLFP and SCP vide Tables 4.41 and 4.42)

* $P < 0.05$, ** $P < 0.01$

on boarder-line of legal requirement, whereas that of CLFP was lower. The protein content of laboratory paneer was significantly higher in comparison to market paneer. This indicated that the market paneer was made from milk containing much lower fat/SNF than laboratory made samples.

During sensory evaluation of fried and cooked paneer it was noticed that when the paneer samples were pressed to determine crumbliness/firmness, there was sudden expulsion of free moisture from inside the paneer cube. This indicated that during cooking paneer cubes had a tendency to imbibe free water which came out on mastication. Thus there was a significant ($P < 0.01$) increase in moisture content of paneer upon frying and cooking. A phenomena of significant absorption of fat during frying (and cooking) by only those paneer samples that contained lower than 50% fat on dry matter was observed. This could perhaps be attributed to the principle of equilibrium which was reached earlier in high fat paneer but took more time in low fat one, hence higher absorption of fat in latter. The protein content reduced by approximately 1% during frying and cooking apparently as a result of changes during processing.

4.2.4.2.2 <u>Texture of Market Paneer vs Cow Milk and Low Fat Buffalo Milk Paneer</u>: It can visualized from Table 4.51 that SCCP paneer was significantly less elastic ($P < 0.05$), less firm, less smooth and more

Table 4.51 Comparison of sensory textural properties (max.score, 100) between raw and fried and cooked market, cow milk and low fat buffalo milk paneer

| Attribute | MP2 | | SCCP | | CLFP | | SCP | | Methods | Frying |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | FC | R | FC | R | FC | R | FC | F.ratio[b] (CD) | F.ratio[b] (CD) |
| Elasticity | 60.28 | 67.79 | 57.03 | 66.89 | 66.16 | 68.05 | 56.57 | 66.66 | 2.95* (2.41) | 25.09** (1.71) |
| Firmness | 68.41 | 52.30 | 57.22 | 43.08 | 72.58 | 51.74 | 56.04 | 44.71 | 24.10** (2.13) | 41.37** (1.51) |
| Crumbliness | 40.39 | 45.62 | 65.56 | 47.77 | 44.13 | 42.55 | 46.84 | 45.38 | 13.01** (2.86) | 4.84** (2.02) |
| Stickiness | 22.71 | - | 22.92 | - | 18.28 | - | 28.45 | - | 4.87** (3.60) | - ( -) |
| Smoothness | 51.10 | 50.59 | 48.16 | 43.30 | 50.00 | 43.36 | 61.27 | 49.25 | 10.98** (2.15) | 20.73** (1.52) |
| Chewiness | 62.70 | 57.22 | 55.94 | 62.44 | 69.66 | 71.90 | 53.72 | 60.10 | 15.96** (2.58) | 2.36 (-) |
| Juiciness | - | 69.31 | - | 62.08 | - | 56.41 | - | 60.86 | - (-) | 4.21** (3.00) |
| Overall textural quality | 66.23 | 74.70 | 59.32 | 62.29 | 66.80 | 65.28 | 70.73 | 69.40 | 16.87** (1.85) | 4.02* (1.03) |

Average of six replicates (selected randomly from total 8 for SCCP, CLFP and SCP vide Tables 4.43 and 4.45)

[b] Based on arc-sine values vide Appendix XV

* $P < 0.05$, ** $P < 0.01$

crumbly ($P < 0.01$) than other samples. Its overall textural quality was also significantly ($P < 0.01$) less desirable compared to that of market paneer, SCP paneer was however similar to market paneer in this regard. Concomitant objective textural evaluation (Table 4.52) revealed that SCCP was significantly less hard ($P < 0.05$), gummy and chewy ($P < 0.01$) than market paneer. SCP having similar hardness as SCCP was rated better for its overall sensory textural quality presumably due to its low springiness (Table 4.52) and/or high smoothness score (Table 4.51). However, SCP was also less elastic ($P < 0.05$), less firm ($P < 0.01$), more crumbly ($P < 0.01$) and less chewy than market paneer (Table 4.51).

Low fat buffalo milk paneer (CLFP) was more elastic ($P < 0.05$), almost similar in firmness and crumbliness and more chewy ($P < 0.01$) and less smooth ($P < 0.01$) as compared to market paneer, was significantly ($P < 0.01$) less desirable than market paneer but more so than SCP (Table 4.51).

Further it can be observed that frying and cooking had similar effect on the sensory and instrumental textural characteristics of cow milk and low fat buffalo milk paneer as observed in the case of buffalo milk paneer (Tables 4.48 and 4.49). The acceptability of fried and cooked paneer improved slightly but significantly ($P < 0.05$) perhaps due to the structural changes effected by frying and cooking as also observed in the case of buffalo milk paneer.

Table 4.52 Comparison of instrumental textural properties of raw and fried and cooked paneer from market and cow as well as low fat buffalo milk

| Attribute | MP2 | | SCLP | | CLFP | | SCP | | Methods | Frying |
|---|---|---|---|---|---|---|---|---|---|---|
| | R | FC | R | FC | R | FC | R | FC | F.ratio (CD) | F.ratio (CD) |
| Hardness, mN | 31.27 | 10.19 | 22.46 | 7.58 | 30.81 | 8.81 | 19.66 | 9.16 | 4.03* (4.63) | 112.46** (3.28) |
| Cohesiveness | 0.67 | 0.72 | 0.66 | 0.69 | 0.72 | 0.63 | 0.66 | 0.65 | 1.23 (-) | 0.07 (-) |
| Springiness, mm | 8.71 | 9.92 | 7.42 | 9.71 | 7.46 | 9.79 | 6.96 | 8.88 | 2.42 (-) | 27.87** (0.75) |
| Gumminess, mN | 20.63 | 7.27 | 14.92 | 5.30 | 22.01 | 5.22 | 12.97 | 5.93 | 5.27** (2.92) | 132.63** (2.06) |
| Chewiness, mN.mm | 181.43 | 74.08 | 114.11 | 48.01 | 165.51 | 50.96 | 90.64 | 52.67 | 6.61 (28.57) | 66.99** (20.20) |

Average of six replicates (selected randomly from total 8 for SCLP, CLFP and SCP vide Tables 4.44 and 4.46)

* P ∠ 0.05, ** P ∠ 0.01

### 4.2.5 Relationships between Instrumental and Sensory Textural Attributes and Chemical Constituents of Paneer

Relationships between sensory textural attributes and instrumental measurements, and between these attributes and the chemical constituents of the product can be of great practical utility as stated earlier (vide 4.1.6). The texture of raw paneer has been shown to be influenced by the fat content of milk, processing parameters of milk, and conditions of coagulation and pressing (Bhattacharya *et al*., 1971; Arora and Gupta, 1980; Chawla, 1981; Sachdeva *et al*., 1985; Kulshreshta *et al*., 1987; Sachdeva and Singh, 1988). The role of frying and cooking on the texture of paneer has also been found to be equally important (Arora and Gupta, 1980; Chawla *et al*., 1985; Sachdeva and Singh, 1988 and Kalab *et al*., 1988). However, no systematic attempts have been made so far to establish the relationships of all these parameters with the texture of paneer. Therefore, the pooled observations on rheological (instrumental measurements) and sensory textural properties, and compositional data of raw paneer and fried and cooked paneer were separately subjected to correlation and regression analyses to derive possible relationships among them.

4.2.5.1 Relationships between Instrumental and Sensory Textural Properties of Paneer: The coefficients of linear correlations between the Instron measurements and sensory attributes of raw, and fried and cooked paneer have been presented in Table 4.53 and 4.54, respectively.

The Instron hardness of raw paneer showed significant correlation ($P < 0.01$) with sensory elasticity, firmness, stickiness and chewiness and to a lesser but significant extent ($P < 0.05$) with crumbliness (Table 4.53). However, hardness did not show any relationship with smoothness and overall sensory textural quality. Thus, as the instrumental hardness of paneer increased, its sensorily perceived firmness, elasticity and chewiness also increased, while crumbliness and stickiness decreased, although such variations were not reflected in the overall textural quality of the product.

It can be seen from the Table 4.53 that the Instron hardness of fried and cooked paneer was also significantly correlated with all the sensory textural properties except crumbliness. Greater the hardness, greater was the firmness ($P < 0.01$) and chewiness ($P < 0.05$) and lower the elasticity, smoothness and juiciness ($P < 0.01$). Moreover, the instrumental hardness showed significant ($P < 0.05$) negative correlation with the overall texture score, thereby indicating that hardness was a better parameter for fried and cooked paneer than for raw paneer.

Cohesiveness of raw paneer showed significant correlation ($P < 0.01$) with smoothness, but such a relationship was not evident in fried and cooked paneer. However, cohesiveness of fried and cooked paneer showed

Table 4.53 Coefficients of correlation[a] (simple) between sensory and instrumental textural properties of paneer

| Attribute | Hardness (H) | Cohesiveness (Co) | Springiness (Sp) | Gumminess (Gu) | Chewiness (Ch) |
|---|---|---|---|---|---|
| Elasticity (SE) | 0.30** | -0.02 | 0.03 | 0.34** | 0.31** |
| Firmness (SF) | 0.64** | -0.09 | 0.32** | 0.70** | 0.69** |
| Crumbliness (SCR) | -0.23* | 0.08 | -0.03 | -0.22* | -0.19 |
| Stickiness (SST) | -0.55** | 0.11 | -0.07 | -0.58** | -0.52** |
| Smoothness (SSM) | -0.02 | -0.31** | -0.29** | -0.08 | -0.12 |
| Chewiness (SCH) | 0.49** | 0.09 | 0.23* | 0.56** | 0.55** |
| Overall textural quality (SOTQ) | -0.05 | -0.04 | -0.36** | -0.09 | -0.14 |

[a] Based on 64 observations

* $P < 0.05$, ** $P < 0.01$

Table 4.54 Coefficients of correlation[a] (simple) between instrumental and sensory textural properties of fried and cooked paneer

| Attribute | Hardness (H) | Cohesiveness (Co) | Springiness (Sp) | Gumminess (Gu) | Chewiness (Ch) |
|---|---|---|---|---|---|
| Elasticity (SE) | -0.39** | -0.26* | 0.01 | -0.42** | -0.36** |
| Firmness (SF) | 0.61** | 0.21* | 0.04 | 0.61** | 0.54** |
| Crumbliness (SCR) | 0.03 | 0.04 | 0.05 | 0.01 | 0.04 |
| Smoothness (SSM) | -0.32** | -0.09 | -0.19 | -0.32** | -0.31** |
| Juiciness (SJU) | -0.48** | 0.01 | -0.01 | -0.44** | -0.37** |
| Chewiness (SCH) | 0.20 | -0.13 | 0.08 | 0.16 | 0.15 |
| Overall textural quality (SOTQ) | -0.26* | -0.11 | -0.10 | -0.27* | -0.26* |

[a] Based on 84 observations

* P ∠ 0.05, ** P ∠ 0.01

significant relationship ($P < 0.05$) with the product's sensory elasticity and firmness. Thus while more cohesiveness in raw paneer meant less smoothness, for fried and cooked paneer higher cohesiveness was indicative of lower elasticity and more firmness. However, the level of relationships observed was considerably low.

Springiness of fried and cooked paneer did not show any significant relationship with its sensory attributes, however, that for raw paneer more significant correlation with firmness ($P < 0.01$), smoothness ($P < 0.01$), chewiness ($P < 0.05$) and overall textural quality ($P < 0.01$). Thus overall textural quality of raw paneer could be appreciably decided by its springiness. As the sponginess (i.e. springiness) increased in raw paneer, it became more firm and chewy but less smooth and desirable from the point of view of its overall texture.

Since gumminess and chewiness are calculated from hardness these parameters exhibited almost similar relationships with the sensory attributes of raw as well as fried and cooked paneers as that shown by Instron hardness. However, instrumental chewiness of fried and cooked paneer did not show any significant correlation with the sensory chewiness of the product. This could be attributed to the fact that the chewiness of fried and cooked paneer perceived through mastication, was obviously different from the chewiness determined by Instron, the latter being a product of hardness (which was very low in this paneer) cohesiveness and springiness.

Thus, significant correlations were observed between sensory firmness and Instron hardness, gumminess and chewiness, hardness being most important in this regard (Table 4.53 and 4.54). The predictability of sensory firmness of raw paneer could be enhanced if Instron hardness, was coupled with springiness and cohesiveness employing a logarithmic scale as is evident from the following regression equation which explained 52% variation in the sensory firmness:

$$\ln SF = 3.42 + 0.25 \ln H + 0.40 \ln Co + 0.01 \ln SP \quad (R^2 = 0.52)$$

4.2.5.2 <u>Relationship between Instron Texture Measurements and Chemical Constituents of Paneer</u>: Significant correlations ($P < 0.01$) were observed between instrumental hardness, gumminess and chewiness and moisture, fat, protein and calcium contents of raw paneer (Table 4.55). All correlations were positive except those with moisture. Thus as the fat, protein, calcium and total solids content of paneer increased so also the hardness, gumminess and chewiness. Harder paneer naturally had higher calcium content, and lower pH caused the product to be more springy. Cohesiveness exhibited significant ($P < 0.01$) correlation with moisture, fat, fat and protein on dry matter basis. Springiness on the other hand, showed significant correlation only with calcium and pH, the relationship with the latter being negative.

Table 4.55 Coefficients of correlation[a] (simple) between instrumental texture measurements and compositional characteristic of paneer

| Attribute | Hardness (H) | Cohesiveness (Co) | Springiness (Sp) | Gumminess (Gu) | Chewiness (Ch) |
|---|---|---|---|---|---|
| Moisture, % (Mo) | -0.59** | 0.42** | 0.11 | -0.60** | -0.52** |
| Fat, % (F) | 0.48** | -0.52** | -0.16 | 0.45** | 0.38** |
| Fat in dry matter, % (FDM) | 0.19 | -0.48** | -0.18 | 0.13 | 0.08 |
| Protein, % (PR) | 0.40** | -0.04 | 0.00 | 0.47** | 0.42** |
| Protein in dry matter, % (PRDM) | -0.15 | 0.44** | 0.12 | -0.08 | -0.05 |
| Calcium, % (Ca) | 0.45** | 0.03 | 0.21* | 0.48** | 0.47** |
| pH | -0.18 | -0.04 | -0.25* | -0.22* | -0.26* |

[a] Based on 84 observations

* P ∠ 0.05, ** P ∠ 0.01

It can be seen from the interrelationship amongst the different chemical constituents (Table 4.56) that fat and protein contents were significantly ($P \angle 0.01$) correlated with the moisture content of raw paneer. The moisture content, showing a higher correlation coefficient with hardness as compared to fat and protein (Table 4.56), was considered to be the most important compositional attribute. The multiple-log-linear regression equation given below clearly indicates that the moisture content together with calcium and pH could substantially (59%) predict the hardness of the product:

$$\ln H = 28.47-2.99 \ln Mo + 1.08 \ln Ca - 7.32 \ln pH \quad (R^2 = 0.59)$$

As can be visualized from Table 4.57, significant correlation was found between moisture, fat and protein content and Instron hardness, gumminess and chewiness. Springiness showed significant correlation ($P \angle 0.05$) only with moisture, whereas cohesiveness did not correlate significantly with any of the constituents. Hence as the solids content increased the fried and cooked paneer tended to be harder, springier and more chewy. The same was true for fat and protein contents in relation to hardness, chewiness and gumminess. Apparently, hardness was the most important attribute which was affected by chemical composition of both raw and fried and cooked paneer. Its correlations with different compositional constituents was smaller and not high enough to permit regression analysis. The moisture content alone seemed to exhibit significant

Table 4.56 Coefficients of correlation[a] (simple) among compositional parameters of raw paneer

| Attribute | Mo | F | FDM | PR | PROM | Ca | pH |
|---|---|---|---|---|---|---|---|
| Moisture, % (Mo) | - | | | | | | |
| Fat, % (F) | -0.39** | - | | | | | |
| Fat in dry matter, % (FDM) | -0.50** | 0.34 | - | | | | |
| Protein, % (PR) | -0.67** | 0.26 | -0.29** | - | | | |
| Protein in dry matter, % (PROM) | 0.30** | -0.69** | -0.96** | 0.51** | - | | |
| Calcium, % (Ca) | -0.13 | -0.04 | -0.26* | 0.24* | 0.21* | - | |
| pH | 0.02 | 0.06 | 0.12 | -0.12 | 0.18 | 0.06 | - |

[a] Based on 84 observations

* P ∠ 0.05, ** P ∠ 0.01

Table 4.57 Coefficients of correlation[a] (simple) between instrumental texture measurements and compositional characteristics of fried and cooked paneer

| Attribute | Hardness (H) | Cohesiveness (Co) | Springiness (Sp) | Gumminess (Gu) | Chewiness (Ch) |
|---|---|---|---|---|---|
| Moisture, % (mO) | -0.51** | 0.12 | -0.21* | -0.49** | -0.51** |
| Fat, % (F) | 0.26* | -0.12 | 0.09 | 0.26* | 0.27* |
| Fat in dry matter, % (FDM) | -0.30** | -0.03 | -0.14 | -0.28** | -0.29** |
| Protein, % (PR) | 0.47** | -0.12 | 0.16 | 0.44** | 0.44** |
| Protein in dry matter, % (PRDM) | 0.25* | -0.07 | 0.04 | 0.22** | 0.20 |

[a] Based on 84 observations

* $P < 0.05$, ** $P < 0.01$

($P < 0.01$) correlation with in fat and protein and, therefore could be considered as the most important constituent in fried and cooked paneer as far as instrumental texture was concerned (Table 4.58).

4.3.5.3 <u>Relationships between Sensory Texture and Chemical Constituents of Paneer:</u> As revealed from Table 4.59, moisture content of raw paneer showed significant correlation with all the sensory textural properties, implying that higher the moisture content lower would be the elasticity, firmness, smoothness and chewiness ($P < 0.01$) and higher would be the crumbliness ($P < 0.05$) and stickiness ($P < 0.01$). The moisture content showed an inverse relation with the overall textural quality ($P < 0.01$). The fat content also exhibited significant correlation with almost all sensory textural properties except firmness and chewiness, the relationship with the overall textural quality being direct. Thus, besides the moisture content, the fat content also had a definite effect on the textural acceptability of raw paneer. Chawla <u>et al</u>. (1985) observed a similar effect of fat content of paneer on its body and texture quality. An increase in protein content in raw paneer seemed to significantly increase the elasticity, firmness and chewiness ($P < 0.01$), and decrease stickiness ($P < 0.05$) (Table 4.59). The calcium content of raw paneer positively correlated with its elasticity ($P < 0.05$), firmness and chewiness ($P < 0.01$) and negatively correlated

Table 4.58 Coefficients of correlation[a] (simple) among compositional parameters of fried and cooked paneer

| Attribute | Mo | F | FDM | PR | PRDM |
|---|---|---|---|---|---|
| Moisture, % (Mo) | - | | | | |
| Fat, % (F) | -0.78** | - | | | |
| Fat in dry matter, % (FDM) | 0.15 | 0.50** | - | | |
| Protein, % (PR) | -0.78** | 0.26* | -0.67** | - | |
| Protein in dry matter, % (PRDM) | -0.27* | -0.32** | -0.39** | 0.31** | - |

[a] Based on 84 observations

* $P < 0.05$, ** $P < 0.01$

Table 4.59 Coefficients of correlation[a] (simple) between sensory textural attributes and compositional parameters of paneer

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| Attribute | SE | SF | SCR | SST | SSM | SCH | SOTQ |
|---|---|---|---|---|---|---|---|
| Mo | -0.35** | -0.41** | 0.22* | 0.48** | -0.37** | -0.28** | -0.26* |
| F | 0.22* | 0.19 | -0.31** | -0.46** | 0.50** | 0.01 | 0.35** |
| FDM | -0.01 | -0.15 | -0.32** | -0.28** | 0.50** | -0.34** | 0.36** |
| PR | 0.35** | 0.51** | 0.07 | -0.22* | 0.00 | 0.56** | 0.00 |
| PRDM | 0.06 | 0.20 | 0.33** | 0.25* | -0.43** | 0.41** | -0.30** |
| Ca | 0.27* | 0.39** | 0.16 | -0.38** | -0.16 | 0.31** | -0.14 |
| pH | -0.13 | -0.35** | -0.03 | 0.08 | 0.32** | -0.16 | 0.23 |

[a] Based on 84 observations

* P $\angle$ 0.05, ** P $\angle$ 0.01

with stickiness ($P < 0.01$) but its correlation with other properties and the overall sensory textural quality was non-significant. The pH of raw paneer directly affected its smoothness ($P < 0.01$) and overall textural quality ($P < 0.05$), but was inversely related to its firmness ($P < 0.01$). Because of the interrelationship amongst fat, protein and moisture (Table 4.56), and the last being related to all the sensory textural properties, moisture alone could be considered as the single most important constituent. Thus the log-linear regression analysis brought out the following prediction equation explaining 50% variation in sensory firmness of raw paneer: ($R^2 = 0.50$)

$$\ln SF = 3.32 + \ln Mo$$

The fat content of fried and cooked paneer did not seem to be correlated (Table 4.60) with any of the sensory textural properties. This was not so with raw paneer. Apparently level of fat content was not important in fried and cooked paneer. Moisture content of paneer (fried and cooked) was obviously very important as it significantly correlated with elasticity, firmness, juiciness and overall textural quality, although protein content correlated with all the sensory textural attributes except crumbliness. Thus moisture and protein content were a very important in fried and cooked paneer as far as their textural attributes were concerned. The significant ($P < 0.01$) correlation between protein and juiciness

Table 4.60 Coefficients of correlation[a] (simple) between sensory textural attributes and compositional parameters of fried and cooked paneer

| Attribute | SE | SF | SCR | SSM | SJU | SCH | SOTQ |
|---|---|---|---|---|---|---|---|
| Mo | 0.23* | -0.33** | -0.17 | 0.18 | 0.41** | -0.20 | 0.27* |
| F | -0.08 | 0.09 | 0.07 | 0.09 | -0.12 | -0.02 | -0.04 |
| FDM | 0.19 | -0.33** | -0.09 | 0.39** | 0.38** | -0.30** | 0.31 |
| PR | -0.25* | 0.36** | 0.12 | -0.29** | -0.54** | 0.29** | -0.34** |
| PRDM | -0.18 | 0.25* | 0.05 | -0.30** | -0.46** | 0.27* | -0.28** |

[a] Based on 84 observations

* $P < 0.05$, ** $P < 0.01$

implied that the textural changes upon frying and subsequent cooking were related to unexplored qualitative changes in the protein which resulted in its increased juiciness.

In general, moisture and protein contents were related to sensory textural properties in opposite manners and the degree of their correlation was significant but rather low, hence no regression analysis was attempted.

4.2.5.4 <u>Relationships among Instron Parameters of Paneer</u>: As shown in Table 4.61, the highly significant ($P < 0.01$) correlations between hardness and cohesiveness, and hardness and springiness of raw paneer indicate that the structural properties of the product determining the hardness had considerable influence on the cohesiveness and springiness. These correlations also imply that the factors affecting the hardness of raw paneer also influenced the cohesiveness (inversely) and springiness (directly). However, correlation coefficients were not high enough to permit adequate predictions. As mentioned earlier (vide 4.1.6.4), gumminess and chewiness being derived properties, their correlations with hardness, cohesiveness and springiness were only expected.

As shown in Table 4.62, the correlation between hardness and cohesiveness observed for raw paneer disappeared upon frying and cooking, but springiness showed significant correlation with ($P < 0.01$) with hardness.

Table 4.61 Coefficients of correlation[a] (simple) among rheological properties of paneer

| Attribute | H | Co | Sp | Gu | Ch |
|---|---|---|---|---|---|
| Hardness | - | | | | |
| Cohesiveness | -0.43** | - | | | |
| Springiness | 0.39** | -0.05 | - | | |
| Gumminess | 0.97** | -0.33** | 0.39** | - | |
| Chewiness | 0.95** | -0.32** | 0.58** | 0.97** | - |

[a] Based on 84 observations

* P ∠ 0.05, ** P ∠ 0.01

Table 4.62 Coefficients of correlation[a] (simple) among rheological properties of fried and cooked paneer

| Attribute | H | Co | Sp | Gu | Ch |
|---|---|---|---|---|---|
| Hardness | - | | | | |
| Cohesiveness | 0.03 | - | | | |
| Springiness | 0.29** | -0.13 | - | | |
| Gumminess | 0.96** | 0.23* | 0.27* | - | |
| Chewiness | 0.92** | 0.20* | 0.52** | 0.94** | - |

[a] Based on 84 observations

* P ∠ 0.05, ** P ∠ 0.01

This may be attributed to the 'skin' forming (or case-hardening) effect of frying which generally tended to result in higher value for Instron cohesiveness (vide Tables 4.49 and 4.51) irrespective of hardness. While cohesiveness and springiness were not correlated with each other, gumminess and chewiness of fried and cooked paneer were significantly correlated with its hardness, cohesiveness and springiness as was the case with raw paneer. However, the quantum of relationship was not adequate enough to enable prediction of one property from others.

4.2.5.5 <u>Interrelationships among Sensory Textural Properties of Paneer:</u> It can be visualized from Table 4.63 that sensory elasticity was significantly correlated with all other sensory properties except smoothness and overall textural quality. Sensory firmness was also highly correlated with stickiness and chewiness. The overall sensory textural quality of raw paneer was inversely correlated ($P < 0.01$) with crumbliness and chewiness but directly with smoothness, indicating thereby that smoothness was the most important sensory attribute. The higher correlation coefficient ($r = 0.73$) was observed between chewiness and firmness, two of the most important attributes of paneer texture, the relationship being expressed as a linear regression equation stated below:

$$SCH = 11.65 + 0.72\ SF \qquad (R^2 = 0.54)$$

Table 4.63 Coefficients of correlation[a] (simple) among sensory textural characteristics of raw paneer

| Attribute | SE | SF | SCR | SST | SSM | SCH | SOTQ |
|---|---|---|---|---|---|---|---|
| Elasticity (SE) | - | | | | | | |
| Firmness (SF) | 0.50** | - | | | | | |
| Crumbliness (SCR) | -0.24* | -0.18 | - | | | | |
| Stickiness (SST) | -0.28** | -0.53** | 0.23* | - | | | |
| Smoothness (SSM) | 0.17 | -0.28** | -0.24* | 0.11 | - | | |
| Chewiness (SCH) | 0.28** | 0.73** | -0.08 | -0.47** | -0.40** | - | |
| Overall textural quality (SOTQ) | 0.12 | -0.16 | -0.38** | -0.07 | 0.54** | -0.29** | - |

[a] Based on 84 observations

* $P < 0.05$, ** $P < 0.01$

However, individual contribution of each sensory textural property to its overall textural quality seemed to be very small, as the multiple linear regression equation between overall sensory texture score of raw paneer and all the sensory textural attributes could explain only 48% variation.

$$SOTQ = 63.12 - 0.04\ SE - 0.01\ SE - 0.19\ SCR - 0.175\ ST + 0.47\ SSM - 0.13\ SCH \quad ........(R^2 = 0.48)$$

This indicated that besides smoothness (43%), crumbliness, stickiness and chewiness were important textural aspect of raw paneer affecting its overall textural quality.

The extent of interrelationship among the subjective textural aspects of fried and cooked paneer could be seen from Table 4.64. Elasticity was significantly correlated ($P < 0.01$) with all attributes except crumbliness and chewiness, juiciness showing the highest coefficient of correlation. Sensory firmness showed significant, but inverse, correlation with smoothness and juiciness and was directly correlated with chewiness. Among important correlations was that between smoothness and juiciness. With regard to overall sensory textural quality, juiciness appeared to be the most important determinant, followed by smoothness, crumbliness and elasticity, all showing significant ($P < 0.01$) correlations although these were not high enough to permit effective prediction. Nevertheless, a multiple regression analysis between overall textural quality and different sensory attributes yield the following

Table 4.64 Coefficients of correlation[a] (simple) among sensory textural characteristics of fried and cooked paneer

| Attribute | SE | SF | SCR | SSM | SJU | SCH | SOTQ |
|---|---|---|---|---|---|---|---|
| Elasticity (SE) | - | | | | | | |
| Firmness (SF) | -0.34** | - | | | | | |
| Crumbliness (SCR) | -0.16 | 0.06 | - | | | | |
| Smoothness (SSM) | 0.32** | -0.26* | 0.04 | - | | | |
| Juiciness (SJU) | 0.53** | -0.36** | -0.16 | 0.43** | - | | |
| Chewiness (SCH) | 0.07 | 0.37** | -0.32** | -0.36** | -0.28** | - | |
| Overall textural quality (SOTQ) | 0.34** | -0.02 | -0.38** | 0.51** | 0.55** | -0.06 | - |

[a] Based on 84 observations

* $P < 0.05$, ** $P < 0.01$

linear equation, which could explain 57% variation in the overall sensory textural quality:

$$SOTQ = 16.94 + 0.02\ SE + 0.22\ SF - 0.30\ SCR + 0.53\ SSM + 0.44\ SJU - 0.0007\ SCH \qquad (R^2 = 0.57)$$

It could thus be seen that smoothness, crumbliness and chewiness were observed to be important sensory criteria in deciding overall texture of raw paneer, whereas juiciness, smoothness, crumbliness and elasticity were so for fried and cooked paneer.

## 4.3 CHHANA-BASED SWEETS

### 4.3.1 Rasogolla

4.3.1.1 Composition: The composition of three different varieties SL, NL and SG (Small, normal and sponge, respectively) obtained from the renowned shops (B and K) has been given in Table 4.65. The moisture ($P < 0.01$), protein ($P < 0.05$) and carbohydrate ($P < 0.01$) contents varied significantly between the shops. The moisture ($P < 0.01$), ash ($P < 0.05$) and carbohydrate ($P < 0.01$) contents of varieties SL and NL were significantly higher and the fat and protein contents were significantly ($P < 0.01$) lower than the corresponding values for SG. Thus while varieties SL and NL differed only in size and not in composition, both were significantly different from SG in composition. Variety-wise variations in the composition of market Rasogolla were also observed by Mitra et al. (1967).

Table 4.65 Average composition of market Rasogolla

| Constituent | BSL | KSL | BNL | KNL | BSG | KSG | Variety | | Vendor | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | F.ratio | CD | F.ratio | CD |
| Moisture, % | 44.00 | 37.90 | 43.76 | 33.26 | 53.84 | 50.42 | 35.03** | 3.21 | 15.94** | 2.62 |
| Fat, % | 4.15 | 4.19 | 4.05 | 4.23 | 5.70 | 5.11 | 11.65** | 0.63 | 0.26 | - |
| Protein, % | 5.71 | 5.26 | 5.76 | 5.28 | 7.12 | 6.28 | 14.00** | 0.54 | 7.69* | 0.44 |
| Ash, % | 0.64 | 0.69 | 0.68 | 0.68 | 0.60 | 0.61 | 4.99* | 0.05 | 0.62 | - |
| Carbohydrate, % (by diff) | 45.49 | 51.96 | 45.75 | 51.56 | 32.73 | 37.59 | 55.68** | 3.09 | 22.34** | 2.52 |

Average of five replicates

SL, NL, SG represents variety of Rasogolla

B, K represents the vendor

* $P \angle$ 0.05, ** $P \angle$ 0.01

The mean composition of sponge Rasogolla (52.12% moisture, 5.41% fat, 6.70% protein and 35.16% carbohydrate) observed in this study was similar to that reported by Mitra et al. (1967) (50% moisture, 5.3% fat, 6.4% protein and 37.0% sucrose) except for the protein content. The average composition of varieties SL and NL (39.73% moisture, 4.16% fat, 5.50% protein and 48.69% carbohydrate) was in the range reported for the market product by Sharma and Zariwala (1975) and (except for moisture) by Sen and Rajorhia (1987).

4.3.1.2 Textural Properties: Rasogolla should desirably have round shape, smooth body and spongy texture (Soni et al., 1980). The texture of Rasogolla is monitored by the same factors affecting its composition. The objective as well as sensory textural properties of market Rasogolla of the present study have been presented in Table 4.66 and 4.67, respectively.

It can be visualized from Table 4.67 that the variety SG (sponge) had significantly ($P < 0.01$) lower hardness and gumminess and higher cohesiveness, springiness and greater expressible syrup as compared to varieties SL and NL. However, SL and NL did not differ significantly in their objectively measured physical properties.

A similar picture evolved in relation to sensory perception of texture of Rasogolla (Table 4.66). The variety SG was found to be more elastic, more juicy and more chewy, and less firm, less smooth and less sticky in

Table 4.66 Sensory textural properties (max.score, 100) of market Rasogolla

| Attribute | BSL | KSL | BNL | KNL | BSG | KSG | Variety | | Vendor | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | F.ratio[b] | CD[b] | F.ratio[b] | CD[b] |
| Elasticity | 47.14 | 43.08 | 47.42 | 44.55 | 71.75 | 72.65 | 63.74** | 3.16 | 0.75 | - |
| Firmness | 52.55 | 54.91 | 49.98 | 61.93 | 41.35 | 42.09 | 14.94** | 3.16 | 4.91* | 2.58 |
| Crumbliness | 55.28 | 50.31 | 58.48 | 50.24 | 57.60 | 37.09 | 1.75 | - | 12.10** | 3.65 |
| Stickiness | 27.35 | 31.90 | 27.28 | 32.47 | 19.34 | 18.10 | 6.91** | 4.51 | 0.85 | - |
| Juiciness | 58.18 | 61.34 | 61.20 | 63.01 | 65.20 | 69.73 | 4.30* | 3.15 | 2.10 | - |
| Smoothness | 50.49 | 57.63 | 46.81 | 52.22 | 41.57 | 38.70 | 11.47** | 3.38 | 1.79 | - |
| Chewiness | 46.79 | 42.89 | 47.89 | 45.05 | 58.34 | 68.78 | 37.20** | 2.78 | 0.36 | - |
| Overall textural quality | 68.50 | 75.02 | 69.05 | 72.34 | 67.26 | 69.42 | 3.00 | - | 11.62** | 1.45 |

Average of five replicates

[b] Based on arc-sine values vide Appendix XVI

* P ∠ 0.05, ** P ∠ 0.01

Table 4.67 Instrumental textural properties of market Rasogolla

| Attribute | BSL | KSL | BNL | KNL | BSG | KSG | Variety | | Vendor | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | F.ratio | CD | F.ratio | CD |
| Hardness, mN | 8.12 | 7.57 | 7.84 | 8.62 | 4.67 | 4.51 | 15.05** | 1.47 | 0.00 | - |
| Cohesiveness | 0.58 | 0.59 | 0.56 | 0.54 | 0.70 | 0.69 | 30.93** | 0.04 | 0.01 | - |
| Springiness, mm | 8.65 | 8.20 | 8.90 | 9.05 | 9.90 | 9.78 | 5.20** | 0.89 | 0.15 | - |
| Gumminess, mN | 4.65 | 4.29 | 4.13 | 4.69 | 3.25 | 2.98 | 6.42** | 0.86 | 0.01 | - |
| Chewiness, mN.mm | 40.23 | 35.53 | 36.46 | 43.52 | 31.89 | 28.64 | 3.03 | - | 0.01 | - |
| Juiciness, % gms (expressible syrup) | 29.81 | 25.08 | 27.39 | 21.11 | 37.59 | 39.08 | 48.02** | 3.03 | 6.65* | 2.48 |

Average of five replicates

* P ∠ 0.05, ** P ∠ 0.01

comparison to SL and NL. These variety oriented textural differences, however, were not reflected in the overall texture score, all three varieties differing non-significantly from one another in this regard. Shop-wise variations in the sensory textural quality was highly significant ($P < 0.01$) indicating thereby the differences in the commercial manufacturing practices. Further the significant differences in the product firmness ($P < 0.05$) and crumbliness ($P < 0.01$) were indicative of the possible role of these parameters in deciding the overall textural quality, a less crumbly and more firm product being rated higher (Table 4.67). Also, no objective parameter (Table 4.66) seemed to be able to explain the variation in the overall sensory texture of Rasogolla obtained from different shops.

### 4.3.2 Texture Studies on Sandesh

A preliminary market survey revealed that the size and shape of Sandesh varied widely. Moreover, it was not possible to draw a cylindrical sample for texture assessment using Instron, owing to the too soft or too hard and crumbly nature of Sandesh. Thus the results of only the preliminary studies involving hardness measurement by means of a cone penetrometer in addition sensory evaluation have baen discussed here. Composition of four varieties or types of Sandesh available in Delhi market was also determined.

It can be noted from Table 4.68 that the moisture content of Sandesh varied greatly among the different

Table 4.68 Composition of market Sandesh

| Type[a] | Constituent, % | | | | | |
|---|---|---|---|---|---|---|
| | Moisture | | Fat | | Protein | |
| | Av | Range | Av | Range | Av | Range |
| Narampak (2) | 17.81 | 17.29-18.32 | 15.40 | 13.82-16.98 | 20.34 | 16.39-24.28 |
| Kharapak (1) | 10.20 | | 19.05 | | 15.29 | |
| Kacchagulla (4) | 38.10 | 31.23-44.96 | 16.37 | 11.84-20.89 | 14.55 | 11.02-18.08 |
| Khoa-Sandesh (1) | 27.15 | | 17.12 | | 15.07 | |

[a] Figures in parentheses indicate the number of samples analysed

varieties, ranging from 10.20% to 44.96%. The overall variation of fat and protein in Sandesh, irrespective of variety, ranged from 11.34% to 20.39% and 11.02% to 24.28%, respectively. The moisture contents of Narampak and Kharapak were similar to those reported by Sarkar et al. (1975) for soft grade and hardgrade Sandesh, respectively. However, fat and protein contents observed in the present study were somewhat lower as compared to the values (23.1% and 21.9% fat, and 26.1% and 20.5% protein, for soft grade and hard grade Sandesh, respectively) reported by these workers, which may be attributed to variations in composition of chhana used, level of sugar addition etc. In absence of any available information, the composition of Kacchagulla and Khoa-Sandesh could not be compared. However, the overall composition of Sandesh was found to be in the range reported by Sen and Rajorhia (1987).

Marked variation in the firmness were observed among the varieties of Sandesh as revealed by the results presented in Table 4.69. It can be seen (from the table) that the firmness of Kharapak was greatest followed by Narampak, Kacchagulla and Khoa-Sandesh. Objectively determined hardness (kg/cm$^2$) of the product was in the same order, the highest value for Kharapak (23.9), being followed by Narampak (2.88). Observations on other sensory textural properties revealed that Narampak and Kharapak were less elastic than the other two varieties, all the Sandesh samples were highly crumbly. The Narampak and Kharapak

Table 4.69 Sensory score (max.100) for textural attributes of Sandesh

| Attribute | Type of Sandesh | | | |
|---|---|---|---|---|
| | Narampak | Kharapak | Kacchagulla | Khoa-Sandesh |
| Elasticity | 13.0 (12.0-14.0) | 14.0 | 32.0 (26.0-38.0) | 24.0 |
| Firmness | 57.5 (52.0-63.0) | 78.0 | 50.5 (35.0-66.0) | 43.0 |
| Crumbliness | 75.5 (74.0-77.0) | 66.0 | 68.0 (58.0-78.0) | 63.0 |
| Stickiness | 16.5 (16.0-17.0) | 16.0 | 37.5 (32.0-43.0) | 32.0 |
| Smoothness | 55.5 (51.0-60.0) | 49.0 | 34.5 (20.0-49.0) | 35.0 |
| Chewiness | 42.0 (41.0-43.0) | 40.0 | 57.0 (43.0-71.0) | 60.0 |
| Overall textural quality | 58.5 (57.0-60.0) | 44.0 | 59.0 (49.0-69.0) | 65.0 |

Figures in parentheses indicate the range for sensory attributes varieties were less sticky and more smooth than Kacchagulla and Khoa-Sandesh. Khoa-Sandesh was found to be highly chewy, followed by Kacchagulla, Narampak and Kharapak. These textural observations can be regarded as characteristic of the variety. Yet from the overall textural quality point of view Khoa-Sandesh was rated the best.

# SUMMARY

# AND

# CONCLUSIONS

# 5. SUMMARY AND CONCLUSION

Texture is an important fundamental sensory property of all foods. Its objective measurement belongs to the area of rheology. The knowledge of rheological properties of a food may give important clues to its acceptability. Instrumental measurement of texture is not a novel approach with regard to western milk products like cheese, butter, yoghurt etc. However, no systematic attempts have been made to evaluate textural properties of Indian indigenous milk products. In spite of considerable technological developments during the last three decades, in response to the emphasized need for uniform quality production of indigenous dairy products, little is known about the desirable sensory properties of these products. With this background, the present study was planned to evaluate the objective and sensory textural properties of heat-and-acid coagulated Indian milk products such as chhana, paneer and chhana based sweets like Rasogolla and Sandesh available in popular markets. In case of chhana and paneer samples were prepared in the laboratory using different methods reported in the literature. The textural properties of the most desirable market chhana and paneer samples and laboratory made products were compared. In order to arrive at possible relationships among the compositional and instrumental (Instron) and sensory textural attributes. The results obtained during this investigation have been summarized in this chapter.

## 5.1 CHHANA

5.1.1 Based on sensory analysis market chhana was observed to be relatively less firm, less elastic, less crumbly and less chewy. It had moderate stickiness and was very smooth. Such chhana was rated most desirable with respect to the overall textural quality.

5.1.2 Sensory and instrumental textural attributes, except sensory elasticity and stickiness, and Instron springiness, of market chhana showed significant variations among different samples.

5.1.3 In general, cow milk chhana was observed to be appreciably harder as compared to market chhana, more cohesive and more springy as revealed by Instron measurements.

5.1.4 Also, average cow milk chhana was rated to be sensorily more elastic, firm, crumbly and chewy, but less sticky as compared to market chhana (MC5). However, its smoothness and overall textural quality were similar to market chhana.

5.1.5 Buffalo milk chhana (laboratory made) was also generally much harder, more springy and more chewy as compared to market or cow milk chhana. However, coagulation conditions and delayed straining technique as suggested by Soni *et al.* (1980) resulted in a product that was texturally most desirable among all laboratory made buffalo milk chhanas. This product was highly acceptable and fairly close to market chhana. Other process modifications studied were only partially or not at all helpful in obtaining the desirable textural properties in buffalo milk chhana as indicated by instrumental as well sensory texture evaluations.

5.1.6 The instrumental and sensory textural properties of mixed milk chhana were generally very close to cow milk chhana, and showed more or less similar variations from market chhana as in the case of cow milk chhana.

5.1.7 Based on overall sensory textural quality, cow, buffalo and mixed milk chhana obtained by the method of Soni et al. (1980) was rated the best and was even better than market chhana.

5.1.8 Instrumental hardness of chhana showed significant correlations with all the sensory textural properties. Its highly significant negative correlation with overall textural quality suggested that softness was the most desirable sensory attributes of chhana. Instron hardness was also significantly correlated with other objective textural properties of chhana.

5.1.9 Moisture content of chhana appeared to be the most important compositional factor affecting instrumental as well as sensory textural properties. It could explain most of variation in the instrumental hardness (85%), sensory elasticity (66%) and firmness (74%).

5.1.10 Like instrumental hardness, sensory firmness appeared to be the most important textural attribute. It could explain 67% and 82% variation in elasticity and chewiness, respectively. However, with respect to the overall sensory textural quality of the product, smoothness was most predictive (79%) followed by chewiness (68%) and firmness (59%).

5.1.11 On the bais of significant correlation coefficients, linear regression coefficients were calculated for some of the textural attributes. The overall sensory quality of chhana could be predicted on the basis of chemical parameters or instrumental measurements by means of the following regression equations:

i) $SOTQ = -29.85 + 0.22\ Mo - 65.0\ Ca + 18.66\ pH$

$$R^2 = 0.70$$

ii) $SOTQ = 54.15 - 0.74\ H + 3.10\ Co + 2.47\ Sp$

$$R^2 = 0.55$$

where,

SOTQ = Score for sensory overall textural quality of chhana

Mo = % moisture content of chhana

Ca = % calcium content of chhana

pH = pH of chhana

H = Instron hardness (mN) of chhana

Co = Cohesiveness of chhana

Sp = Springiness (mm) of chhana

## 5.2 PANEER

5.2.1 Almost all the market paneers (obtained from different suppliers) were moderately elastic, firm, crumbly, smooth and chewy, and showed significant variations among themselves and also among batches (replications), however their overall texture could be regarded as fairly desirable.

5.2.2 Instrumentally determined hardness, cohesiveness and chewiness of market paneer also exhibited similar differences as observed in the sensory attributes.

5.2.3 In general, laboratory made buffalo milk paneer was harder, more gummy and more chewy but slightly less cohesive and less springy as compared to average market paneer.

5.2.4 Sensorily, buffalo milk paneer was rated almost equal to market paneer for firmness, elasticity and chewiness. Owing to its lower crumbliness, stickiness and higher smoothness, this paneer was observed to be better than market paneer from the overall textural quality view point.

5.2.5 Addition of calcium chloride to cow milk resulted in a paneer with poor overall texture. Paneer made from cow milk without added calcium chloride was observed to be as good in its overall textural quality as market paneer or buffalo milk paneer, except that it was less hard, chewy and cohesive compared to the latter.

5.2.6 Low fat paneer resembled buffalo milk paneer in its rheology, although it was rated to be more elastic, firm, chewy and less smooth as compared to cow or buffalo milk paneer and market paneer.

5.2.7 In general, frying and cooking of market, buffalo milk, cow milk or low fat buffalo milk paneer resulted in considerably decreased instrumental hardness and chewiness, slightly increased cohesiveness, and appreciably increased springiness.

5.2.8 Frying and cooking of paneer changed the sensory textural perception more or less in the same way as observed instrumentally. However, sensory chewiness increased while Instron chewiness decreased, it thus indicating the difference between sensory perception and Instron measurement of this attribute. Moreover, overall sensory texture was almost similar for all paneer samples, in spite of the textural differences observed in raw paneer.

5.2.9 Frying and cooking of paneer resulted in significantly increased moisture content, and slightly but significantly decreased protein (in DM) content. FDM tended to increase when the initial FDM content was about 50%, but a reverse trend was noticed for raw paneer having about 55% FDM. This was thus suggestive of a probable equilibrium FDM content which was presumably higher than that of low fat paneer but lower than 55% FDM paneer.

5.2.10 Frying and cooking of paneer enhanced the elasticity and chewiness of paneer, and naturally decreased the firmness and smoothness.

5.2.11 With respect to the overall textural quality, the difference between market or buffalo milk paneer was not significant and there was no effect of frying and cooking.

5.2.12 In general, a low level of correlation was observed between sensory and instrumental textural properties, except between sensory firmness and Instron hardness, gumminess and chewiness.

5.2.13 Owing to its high correlations with Instron and sensory textural properties of raw and fried and cooked paneer, moisture content could be regarded as the most important compositional attribute, followed by calcium and pH of raw paneer.

5.2.14 Instrumental hardness of raw, and fried and cooked paneer could be regarded as the most important objective textural parameter.

5.2.15 Sensory smoothness, crumbliness, firmness and chewiness were the determinants of overall texture of raw paneer, whereas for fried and cooked paneer juiciness, smoothness, crumbliness and elasticity were important factors affecting its overall sensory texture.

## 5.3 CHHANA BASED SWEETS

5.3.1 Sponge Rasogolla had significantly lower hardness, gumminess, and higher springiness and cohesiveness, and greater expressible syrup as compared to normal and small Rasogolla.

5.3.2 Sensorily also sponge Rasogolla was found to be more elastic, more juicy and more chewy and less firm, less smooth and less sticky compared to normal and small Rasogolla.

5.3.3 No objective parameter seemed to be able to explain the variation in the overall sensory texture of Rasogolla obtained from different Vendors or among varieties.

5.3.4 Marked variations in the objective hardness and sensory textural properties were noticed among the different Sandesh varieties. All the Sandesh samples were characterized by high crumbliness. Khoa-Sandesh was rated to be most desirable.

## APPENDIX - II

Sensory texture score (arc-sine values) of cow milk chhana

| Attribute | Sample | | | | | |
|---|---|---|---|---|---|---|
| | SC | BDC | DRC | KSC | SDC | IC |
| Elasticity | 38.73 | 52.78 | 55.85 | 56.83 | 56.42 | 53.07 |
| Firmness | 33.50 | 48.40 | 50.15 | 55.66 | 53.73 | 45.18 |
| Crumbliness | 47.25 | 48.95 | 47.20 | 42.52 | 43.36 | 47.50 |
| Stickiness | 42.91 | 37.42 | 36.17 | 35.87 | 37.49 | 35.67 |
| Smoothness | 62.43 | 54.52 | 47.60 | 53.12 | 44.56 | 48.33 |
| Chewiness | 29.23 | 44.14 | 46.75 | 45.79 | 48.01 | 40.86 |
| SOTQ | 62.52 | 52.07 | 47.39 | 49.08 | 47.52 | 50.16 |

# APPENDIX - III

Sensory texture score (arc-sine values) of buffalo milk chhana

| Attribute | Sample | | | | | |
|---|---|---|---|---|---|---|
| | DRBC | KSBC | ICBC | IBC | SBC | KDBC |
| Elasticity | 49.00 | 53.15 | 51.46 | 52.29 | 47.91 | 45.14 |
| Firmness | 61.80 | 56.16 | 53.28 | 56.58 | 37.31 | 59.32 |
| Crumbliness | 42.68 | 44.47 | 43.68 | 43.98 | 39.25 | 54.09 |
| Stickiness | 29.27 | 29.17 | 29.20 | 31.53 | 39.49 | 27.26 |
| Smoothness | 44.85 | 43.52 | 47.45 | 45.44 | 59.78 | 34.16 |
| Chewiness | 54.19 | 52.60 | 47.38 | 48.93 | 32.75 | 54.64 |
| SOTQ | 42.14 | 44.08 | 50.19 | 49.03 | 62.04 | 35.77 |

## APPENDIX - IV

Sensory texture score (arc-sine values) of mixed milk chhana

| Attribute | Sample | | |
|---|---|---|---|
| | IMC | SMC | DRMC |
| Elasticity | 52.42 | 42.05 | 55.34 |
| Firmness | 53.58 | 35.99 | 56.33 |
| Crumbliness | 44.08 | 38.96 | 44.87 |
| Stickiness | 31.92 | 43.42 | 31.46 |
| Smoothness | 44.99 | 60.13 | 44.30 |
| Chewiness | 48.27 | 33.17 | 50.74 |
| SOTQ | 46.32 | 62.18 | 46.80 |

APPENDIX - V

Comparison of sensory texture score (arc-sine values) of market chhana and cow milk chhana

| Attribute | Sample | | | | | | |
|---|---|---|---|---|---|---|---|
| | MCS | SC | BDC | DRC | KSC | SDC | IC |
| Elasticity | 35.46 | 38.70 | 52.78 | 55.85 | 56.33 | 56.42 | 53.07 |
| Firmness | 33.12 | 33.50 | 48.40 | 50.15 | 55.66 | 53.73 | 45.18 |
| Crumbliness | 37.95 | 47.25 | 48.95 | 47.20 | 42.51 | 43.36 | 47.50 |
| Stickiness | 48.41 | 42.91 | 37.42 | 36.17 | 35.87 | 37.49 | 35.67 |
| Smoothness | 55.56 | 62.43 | 54.52 | 47.60 | 53.12 | 44.56 | 48.33 |
| Chewiness | 32.12 | 29.23 | 44.14 | 46.75 | 45.79 | 48.02 | 40.86 |
| SOTQ | 55.57 | 62.52 | 52.07 | 47.39 | 49.08 | 47.52 | 50.16 |

APPENDIX - VI

Comparison of sensory texture score (arc-sine values) of market chhana and buffalo milk chhana

| Attribute | Sample | | | | | | |
|---|---|---|---|---|---|---|---|
| | MCS | DRBC | KSBC | ICBC | IBC | SBC | KDBC |
| Elasticity | 35.46 | 45.00 | 53.15 | 51.46 | 52.29 | 47.91 | 45.14 |
| Firmness | 33.12 | 61.80 | 56.16 | 53.28 | 56.58 | 37.81 | 59.32 |
| Crumbliness | 37.95 | 42.68 | 44.47 | 43.68 | 43.98 | 39.25 | 54.09 |
| Stickiness | 48.41 | 29.27 | 29.17 | 29.20 | 31.53 | 39.49 | 27.26 |
| Smoothness | 55.56 | 44.85 | 43.52 | 49.45 | 45.44 | 59.78 | 34.16 |
| Chewiness | 32.12 | 54.19 | 52.60 | 47.38 | 48.93 | 32.75 | 54.64 |
| SOTQ | 55.57 | 42.14 | 44.08 | 50.19 | 49.03 | 62.04 | 35.77 |

# APPENDIX - VII

Comparison of sensory texture score (arc-sine values) of market and mixed milk chhana

| Attribute | Sample | | | |
|---|---|---|---|---|
| | MC5 | IMC | SMC | DRMC |
| Elasticity | 35.46 | 53.36 | 44.19 | 55.77 |
| Firmness | 33.12 | 53.24 | 34.82 | 54.03 |
| Crumbliness | 37.95 | 43.21 | 35.52 | 42.39 |
| Stickiness | 48.41 | 32.43 | 43.15 | 31.27 |
| Smoothness | 55.58 | 45.49 | 60.01 | 45.73 |
| Chewiness | 32.12 | 45.44 | 33.49 | 48.32 |
| SOTQ | 55.57 | 46.33 | 62.47 | 47.89 |

# APPENDIX - VIII

Sensory texture score (arc-sine values) of market paneer

| Attribute | Sample | | | | | |
|---|---|---|---|---|---|---|
| | MP1 | MP2 | MP3 | MP4 | MP5 | MP6 |
| Elasticity | 51.42 | 50.93 | 49.85 | 49.21 | 51.36 | 46.07 |
| Firmness | 50.46 | 55.80 | 51.96 | 49.56 | 55.98 | 44.09 |
| Crumbliness | 42.27 | 39.46 | 42.71 | 43.85 | 43.04 | 42.71 |
| Stickiness | 29.70 | 28.46 | 30.22 | 30.46 | 26.34 | 33.43 |
| Smoothness | 44.56 | 45.63 | 44.94 | 45.95 | 40.59 | 48.53 |
| Chewiness | 47.00 | 52.36 | 48.46 | 46.43 | 50.57 | 42.17 |
| SOTQ | 52.09 | 54.47 | 49.93 | 52.94 | 48.01 | 53.47 |

# APPENDIX - IX

Sensory texture score (arc-sine values) of fried and cooked market paneer

| Attribute | Sample | | | | | |
|---|---|---|---|---|---|---|
| | MPF1 | MPF2 | MPF3 | MPF4 | MPF5 | MPF6 |
| Elasticity | 54.64 | 55.42 | 50.99 | 53.28 | 53.49 | 54.12 |
| Firmness | 47.28 | 46.32 | 50.02 | 47.91 | 52.73 | 41.27 |
| Crumbliness | 43.56 | 42.49 | 45.06 | 46.33 | 44.95 | 48.08 |
| Stickiness | 29.85 | 30.05 | 30.54 | 29.72 | 28.19 | 30.58 |
| Smoothness | 42.42 | 45.34 | 40.89 | 42.44 | 38.97 | 41.15 |
| Chewiness | 52.28 | 49.15 | 51.01 | 51.57 | 53.93 | 46.84 |
| Juiciness | 53.98 | 56.36 | 50.32 | 50.84 | 49.88 | 52.83 |
| SOTQ | 55.64 | 59.80 | 53.05 | 54.94 | 52.68 | 51.73 |

## APPENDIX - X

Sensory texture score (arc-sine values) of buffalo milk paneer

| Attribute | Sample | | |
|---|---|---|---|
| | SBP | BBP | RBP |
| Elasticity | 51.94 | 52.16 | 53.06 |
| Firmness | 53.88 | 49.49 | 53.61 |
| Crumbliness | 38.85 | 40.97 | 38.15 |
| Stickiness | 24.39 | 23.60 | 22.37 |
| Smoothness | 52.03 | 52.48 | 51.95 |
| Chewiness | 47.15 | 45.92 | 48.37 |
| SOTQ | 58.19 | 58.53 | 58.52 |

## APPENDIX - XI

Sensory texture score (arc-sine values) of fried and cooked buffalo milk paneer

| Attribute | Sample | | |
|---|---|---|---|
| | SBPF | BBPF | RBPF |
| Elasticity | 55.59 | 57.30 | 58.13 |
| Firmness | 42.37 | 42.09 | 42.62 |
| Crumbliness | 41.56 | 40.54 | 40.53 |
| Smoothness | 45.10 | 43.54 | 43.64 |
| Juiciness | 54.27 | 55.77 | 56.69 |
| Chewiness | 50.19 | 52.82 | 52.40 |
| SOTQ | 57.78 | 57.92 | 57.07 |

## APPENDIX - XII

Sensory texture score (arc-sine values) of cow milk and low fat buffalo milk paneer

| Attribute | Sample | | |
|---|---|---|---|
| | SCCP | CLPP | SCP |
| Elasticity | 49.46 | 54.82 | 49.28 |
| Firmness | 49.34 | 57.93 | 48.24 |
| Crumbliness | 52.70 | 42.49 | 43.26 |
| Stickiness | 28.38 | 25.49 | 32.37 |
| Smoothness | 44.33 | 44.83 | 52.61 |
| Chewiness | 48.95 | 55.95 | 46.67 |
| SOTQ | 51.03 | 55.21 | 57.60 |

## APPENDIX - XIII

Sensory texture score (arc-sine values) of fried and cooked cow milk and low fat buffalo milk paneer

| Attribute | Sample | | |
|---|---|---|---|
| | SCCPF | CLFPF | SCPF |
| Elasticity | 55.33 | 55.68 | 54.81 |
| Firmness | 41.40 | 45.66 | 42.05 |
| Crumbliness | 43.34 | 40.51 | 42.19 |
| Smoothness | 41.28 | 40.54 | 44.09 |
| Juiciness | 51.65 | 49.41 | 50.94 |
| Chewiness | 52.36 | 57.70 | 51.13 |
| SOTQ | 52.22 | 53.99 | 55.44 |

APPENDIX - XIV

Comparison of sensory texture score (arc-sine values) between raw and fried and cooked market as well as buffalo milk paneer

| Attribute | MP2 | | SBP | | BBP | | RBP | |
|---|---|---|---|---|---|---|---|---|
| | R | FC | R | FC | R | FC | R | FC |
| Elasticity | 50.93 | 55.42 | 52.16 | 55.16 | 51.80 | 57.14 | 52.73 | 57.79 |
| Firmness | 55.80 | 46.32 | 52.59 | 41.34 | 47.28 | 41.02 | 51.33 | 41.91 |
| Crumbliness | 39.46 | 42.47 | 38.98 | 41.56 | 40.85 | 39.40 | 37.41 | 40.21 |
| Smoothness | 45.63 | 45.34 | 51.52 | 45.26 | 52.84 | 42.88 | 52.52 | 43.37 |
| Chewiness | 52.36 | 49.17 | 45.94 | 49.01 | 44.27 | 52.76 | 46.73 | 51.63 |
| SODQ | 54.47 | 59.80 | 57.93 | 57.87 | 58.85 | 57.19 | 59.48 | 56.45 |
| Stickiness | 28.46 | - | 24.94 | - | 24.00 | - | 23.56 | - |
| Juiciness | - | 53.98 | - | 55.29 | - | 55.91 | - | 56.76 |

APPENDIX - XV

Comparison of sensory texture score (arc-sine values) between raw and fried and cooked market, cow milk and low fat buffalo milk paneer

| Attribute | MP2 | | SCCP | | CLFP | | SCP | |
|---|---|---|---|---|---|---|---|---|
| | R | FC | R | FC | R | FC | R | FC |
| Elasticity | 50.93 | 55.42 | 49.04 | 54.87 | 54.43 | 55.58 | 48.77 | 54.73 |
| Firmness | 55.80 | 46.32 | 49.15 | 41.02 | 58.42 | 45.99 | 48.47 | 41.96 |
| Crumbliness | 39.46 | 42.49 | 54.07 | 43.72 | 41.63 | 40.71 | 43.19 | 42.35 |
| Smoothness | 45.63 | 45.32 | 43.94 | 41.15 | 45.00 | 41.18 | 51.75 | 44.57 |
| Chewiness | 52.36 | 49.17 | 48.41 | 52.20 | 56.58 | 57.99 | 47.13 | 50.82 |
| SOTQ | 54.47 | 59.80 | 50.37 | 52.11 | 54.81 | 53.90 | 57.24 | 56.42 |
| Stickiness | 28.46 | - | 28.60 | - | 25.31 | - | 32.23 | - |
| Juiciness | - | 53.98 | - | 51.99 | - | 48.68 | - | 51.27 |

## APPENDIX - XVI

Sensory texture score (arc-sine values) of market Rasogolla

| Attribute | BSL | KSL | BNL | KNL | BSG | KSG |
|---|---|---|---|---|---|---|
| Elasticity | 43.36 | 41.02 | 43.52 | 41.87 | 57.89 | 58.47 |
| Firmness | 46.46 | 47.82 | 44.93 | 51.90 | 40.02 | 40.45 |
| Crumbliness | 48.03 | 45.18 | 49.88 | 45.14 | 49.37 | 37.52 |
| Stickiness | 31.53 | 34.39 | 31.49 | 34.74 | 26.09 | 25.18 |
| Juiciness | 49.71 | 51.58 | 51.47 | 52.54 | 53.85 | 56.62 |
| Smoothness | 45.28 | 49.39 | 43.17 | 46.27 | 40.03 | 38.47 |
| Chewiness | 43.16 | 40.91 | 43.79 | 42.16 | 50.09 | 56.03 |
| SOTQ | 55.66 | 60.01 | 56.20 | 58.27 | 55.10 | 56.43 |