TECHNOLOGICAL INNOVATION IN MANUFACTURING DUDH CHURPI

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Certified that the work presented in the thesis entitled, 'Technological Innovation in Manufacturing Dudh Churpi' and submitted for the award of the degree of Doctor of Philosophy in Science of the University of North Bengal has been carried out by Sk Aktar Hossain, M.Sc. under our joint supervision at the Centre for Life Sciences, University of North Bengal, Siliguri and the Division of Dairy Technology, National Dairy Research Institute, Karnal. The results incorporated in the thesis have not been submitted for any other degree or diploma elsewhere.

Further certified that the candidate has followed the rules and regulations laid down by the University of North Bengal in carrying out this work.

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Sk Aktar Hossain

ABBREVIATIONS

a_w	=	water acitivity
cal	=	calorie
cm	=	centimeter
°C	=	degree Celcius
dia	=	diameter
g	=	gram
h	=	hour
J	=	joule
°K	=	degree Kelvin
kg	=	kilogram
k cal	=	kilo calories
<	=	less than
l	=	litre
>	=	greater than
m	=	metre
mg	=	milligram
ml	=	millilitre
mm	=	millimetre
min	=	minute
µmol	=	micromole
µm	=	micormetre
N	=	Newton, Normality
nm	=	nannometre
pc	=	piece
s	=	second
v/w	=	volume/weight
w/w	=	weight/weight
w/v	=	weight/volume

CONTENTS

1. INTRODUCTION

Food is a topic on which everybody has his own experience and views. These experiences and views pass through cultural filters and, hence, differ among themselves. Nature has given man the ability and opportunity to select his food from a wide range. However, in reality, these abilities and tastes are greatly restricted by the culture. Traditional foods are, thus, based on culture, custom and natural environment of a region of the world, and concerned by the people for a long time. They are intervented, modified and repetitively processed by human communities. The essential objectives of developing traditional technology were to carry over supplies from the place or time of plenty to those of want. It transpires an essence of knowledge and wisdom, gained by experience and based on trial and error. People might not be able to explain what is going on during storage and processing in terms of scientific language, but they certainly know what they have to do to get the desired product (Dietz 1984). The traditional techniques pass as a trade from older to younger generations in the families; and in some regions of India, the hereditary nature of the profession preparing traditional foods is not only encouraged but also protected by tradition or secular means (Batra and Millner 1976). These methods were based on interdependent factors, such as available raw materials, climate, available energy source, topography, culture and religion.

India is rich in traditional food products and the technologies have achieved a synthesis of Dravidian, Aryan, Mosllem and European cultures. Dudh churpi is such a popular traditional food of several countries of the Indian Subcontinent. It is prepared by the combined action of acid-and-heat treatment of milk and curd. The palatability of the product is enhanced by treating the partially dried product (prechurpi) in concentrated milk-sugar solution. The product is sold as rectangular pieces with creamy to chalky white surface. It is moderately sweet and smoky with hard and compact body. Dudh churpi is consumed by biting or chewing, like betel nut and chewing gum. Chewing of this protein-rich product induces profound salivary secretion during mastication. It is believed to be a great source of energy and is popularly known as 'energy tablet' by the hilly people. The historical documentation on dudh churpi is not available. Although a distinct domination of the Dukpa community is observed in Bhutan, in Sikkim and Darjeeling, village milk producers, irrespective of caste and creed, control the production of dudh churpi, while yak milk is used in Bhutan, milk of dzno (a crossbreed of male yak and indigenous cow) in Sikkim and cow in Darjeeling hills are used in the preparation of dudh churpi.

The sensory quality of food can be depicted in the form of a sensory circle. By the major senses, perimeter of the circle is divided into three zones: appearance, flavour and kinaesthesis (Birch *et al.* 1977). Food product development is generally understood as an em perical method of standardization and product formulation, with respect to sensory appeal and acceptability.

An important fundamental property of all foods is texture which can be regarded as manifestation of the rheological properties of a food. Food texture is defined as the way in which various constituents and structural elements are arranged and combined into a micro- and macro-structure, and the external manifestation of this structure in terms of flow and deformation (de Man 1980). The structural organization of food is, thus, influenced by chemical composition and various physical forces. The external manifestation of food structure is related to the mechanical (rheological) and sensory textural properties of the food. Texture affects processing and handling as it is an important quality attribute, and influences shelf-life, consumer acceptance and food habit (Charm 1962; Matz 1962).It may even be more important than flavour in certain foods (Szczesniak and Kleyn 1963). The knowledge of some of the rheological properties of 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, and for predicting the product quality under certain manufacturing conditions (de Man 1980).

Sensory evaluation of texture in foods belongs to the domain of psychology known as psychophysics that directly concerns the correlation of sensory experience with physical measures (Moskowitz *et al.* 1973). Successfully established psychophysical models could be of considerable significance to the development of new or imitation products and process modifications for existing products (Patil *et al.* 1990).

Quality and convenience, are the two major characteristics that dictate consumers' preference for a food product today. Though freshness, purity and safety are often perceived as indices of food quality, extended shelf-life is now considered as an essential convenience because of the change in traditional family structure and hurried life-style which have changed the existing patterns and food choices of modern consumers (Rao 1993).

The hurdle effect is an illustration of the fact that in most foods several factors (hurdles) contribute to stability and safety. This hurdle effect is of fundamental importance for the preservation of food, since the hurdles in a stable product control microbial spoilage and food poisoning as well as the desirable fermentation (Leistner 1992). There are many processes used for making foods stable and safe, e.g. heating, chilling, freezing, freeze-drying, drying, curing, salting, sugar addition, acidification, fermentation, smoking or oxygen removal. However, these many processes are based on relatively few parameters or hurdles, i.e. high temperature, low temperature, water activity (a_w), pH, rodex potential (Eh), preservatives and competitive microflora. In some of the preservation methods mentioned, these parameters are of major importance, while in others they are only socondary hurdles (Leistner *et al.* 1981). Hurdle technology is now widely used especially in food design, for making new products or modifications of the existing products. Energy consuming hurdles, such as refrigeration, are replaced by hurdles (a_w, pH or Eh) which do not demand energy and still ensure a stable and safe food.

The term, 'shelf stable product (SSP)', was introduced by Leistner and Rödel (1979) for high moisture meats (a_w >0.90), which may be stored after mild heating for weeks or months, but without refrigeration. Stability without refrigeration is an important feature for food since it saves costs by saving energy during distribution and storage. Futhermore, mild heat treatment (70-110°C) is beneficial because it fosters the sensory and nutritional properties of the products (Leistner 1992).

Hurdle concept is now widely used especially in food design for making new products and modification of the existing products. According to this concept, many foods cannot be preserved by a single hurdle alone without affecting their sensory and nutritional properties. With the introduction of two or three more hurdles, the reduction in height and intensity of hurdles could be substantial. By using three or more hurdles together not only the damage to sensory properties is kept to the minimum, but their synergistic action is also exploited for food preservation.

In India, the consumers of traditional milk products are subjected to varied tastes and textures. But little is known about sensory and chemical properties and the different hurdles which greatly influence the acceptability of the product. The production of dudh churpi has remained a traditional family art practised in homes in a crude manner. Consequently, the production has not increased substantially, the quality is not consistent and the shelf-life is short. In order to scale-up its productivity, it is necessary to mordernise the production style and optimize the process conditions. In order to know how the preparation could be mordernized, it is necessary to know the scientific basis of its production. This will shorten the production time, guarantee improved and consistent texture, flavour and nutritional value, increased shelf life, and these, in turn, will increase their general acceptability.

In the light of the scope indicated above, the present study was undertaken with the following objectives:

(a) to obtain information in as much details as possible on the methods used by the local people to prepare dudh churpi;

(b) to assess the physico-chemical quualities and sensory attributes of market samples of dudh churpi prepared in Darjeeling hills, Sikkim and Bhutan;

(c) to elucidate the rheological and sensory textural properties of market samples of dudh churpi;

(d) to correlate sensory attributes with some intrinsic parameters of dudh churpi;

(e) to study the influence of composition on the Instron texture profile of dudh churpi;

(f) to correlate objective (instrumental) data with subjective (sensory) data on texture of dudh churpi so as to enable prediction of the latter from the former;

(g) to optimize different process parameters in the preparation of dudh churpi;

(h) to study the effect of accelerated drying on quality of dudh churpi;

(i) to study the effect of sorbate and different packaging materials on storability of dudh churpi;

(j) to establish water sorption isotherms of dudh churpi and determine the monolayer moisture content and multilayer constants; and

(k) to study the consumer acceptability of the product and the cost of production.

2. REVIEW OF LITERATURE

The development of a traditional product needs an intensive and judicious information regarding the quality of a food which could be available from the manufacturers, of either individual households or small scale sectors.The path from manufacturer to consumer can be improved by adopting these information with the goal of a good quality product having maximum stability and minimum cost. The idea to work on dudh churpi, a shelf stable traditional milk product, was conceived with the objective of its process optimization - experienced from market quality - chemical, sensory and rheological attributes, water activity and related aspects, hurdle concept and hurdle concept hurdle technology, and packaging. Since published works on these aspects are not available for dudh churpi, the qualities of similar products are briefly reviewed.

2.1. Quality and proximate composition

Churpi, a light amber to dark brown coloured, cubical or cylindrical block, is faintly sweet and distinctly smoky with very hard and compact body (Karki 1986; Tamang *et al.* 1988; Katiyar *et al.* 1991; Pal 1994; Pal *et al.* 1993). Pronounced gumminess and chewiness are the important characteristics of this heat-and-acid coagulated milk product. This is used as a chewing gum by the people of the district of Darjeeling of West Bengal, Sikkim, Nepal, Bhutan and Tibet (Pal *et al.* 1993). Churpi contains 2-4% moisture (Batra and Millner 1976). Katiyar *et al.* (1991) reported the mean chemical composition of of churpi (per 100 g): 3.9-4.2 g moisture; 6.6-7.2 g ash; 53.4-57.6 g protein; 20.4-23.2 g carbohydrate; 11.2-12.3 g fat; 407-411 cal metabolizable energy; 2 mg iron; 168-176 mg potassium; 104-106 mg sodium and 70-76 mg calcium.

Kachcha churpi, a low fat chhana-like, traditional milk product contains 68.50-74.54% moisture, 0.43-3.80% fat, 28.53-31.70% protein and 1.52-1.59%

ash (Pal *et al.* 1994). It is consumed either as a condiment or as an ingredient of curries (Tamang *et al.* 1988). A compact mass of hard rubbery body with mild acid flavour is believed to ensure the good quality kachcha churpi (Pal *et al.* 1994).

2.2. Sensory quality

Food product development is generally understood as an emperical method of standardizing a product formulation with respect to sensory appeal and acceptibility. The sensory quality of a food can be identified by its appearance, flavour and kinaesthesis. Appearance is sensed by the eye, flavour is sensed by the pappillae on the tongue and olfactory epithelium of the nose and kinaesthesis or texture is sensed by the muscle endings (Birch *et al.* 1977). This part of psychology deals with sensory perception. In this case, taste and odour are a basic consideration in flavour. Flavour is something that one is equipped to percieve through suitable receptors, namely nose, mouth and related structures. Flavour has three basic components, namely olfactory , gustatory, and tactual, which are concerned respectively with the odour , taste, and feel of a flavour stimulus. Olfactory deals with odour, and the odour of the food taken into the mouthbecomes apparent as vapours passes up the back of the nose into the olfactory area. Whereas variation in odour is almost limitless, taste is connected with a relatively few sensations that are detected in the mouth, and more particularly on the tongue.

Colour is appreciated for its intrinsic aesthetic value and a basis for identification of quality judgement for food products.

Pal *et al.* (1993) studied the sensory characteristics of churpi and found it to be faintly sweet and distinctly smoky with hard and compact body. The colour of churpi was light amber to dark brown. Heavy gumminess and chewability were found to be its main characteristics.

2.3. Textural property.

2.3.1. Specific textural properties

Szczesniak (1963) classified the textural properties into three main groups, namely mechanical, geometrical, and other properties. Mechanical attributes include five primary parameters (hardness, cohesiveness, viscocity, elasticity, and adhesiveness) and three secondary parameters (fracturability, gumminess and chewiness) which are products of two or more primary properties. Bourne (1969) defined elasticity as springiness. Except adhesiveness, primary properties measure the response of food stress and are related to the ability of the to resist disintegration under applied forces (Szczesniak 1963). The arrangement of the constituents of food including the size and shape of particle orientation refers to geometric characteristics and it determines gross and microstructure of food. Other characteristics, such as moisture and fat content contribute to the phenomena observed during instrumental analysis. Civille and Szczesniak (1973) described the phycical and sensory definitions of mechanical characteristics (Table 1) which have widely been accepted for texture profile analysis.

The textural property of churpi was evaluated by sensory textural score card and Instron Universal testing machine (Pal 1994).

2.3.2. Sensory texture profile

Sensory texture profile is defined as the organoleptic analysis of the texture

Table 1. Definition 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
Springiness	Rate at which a material returns to its original condition	Degree to which a product returns to its original size
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 disintigrate a semisolid food to a state ready for swallowing	Denseness that persists throughout mastication

Source: Civille and Szczesniak (1973)

complex of a food in terms of its mechanical, geometrical, fat and moisture characteristics, the degree of each present, and the order in which they appear from first bite through complete mastication (Brandt *et al.* 1963). While developing a standardized methodology for evaluatig the sensory texture of foods, many workers (Szczesnaik 1963; Szczesnaik *et al.* 1963; Brandt *et al.* 1963) proposed a sensory texture profile which was later modified by Sherman (1969) as in Fig. 1.

Pal (1994) quantified elasticity, firmness, crumbliness, smoothness, gumminess, chewiness and overall textural quality by using a 100-point unstructured scale score card for sensory texture complex evaluation of churpi.

2.3.3. Objective texture profile

Texture is composed of several interrelated parameters and it leads to the development of a texture profile which accounts for changes in texture as a result of force, time and temperature (Larmond 1976). For mechanical assessment of texture based on sensory and objective measurements, the texture profile was designed (Szczesnaik *et al.* 1963) and uses the classification of primary and secondary properties as laid down on section 2.3.1.

Pal (1994) reported the Instron textural parameters such as hardness, cohesiveness, springiness, gumminess and chewiness for market as well as laboratory-made churpi.

2.4. Instrumental assessment of food texture

Instrumental evaluation of food texture has come of age as is evidenced by increasing applications of various emperical and imitative methods towards

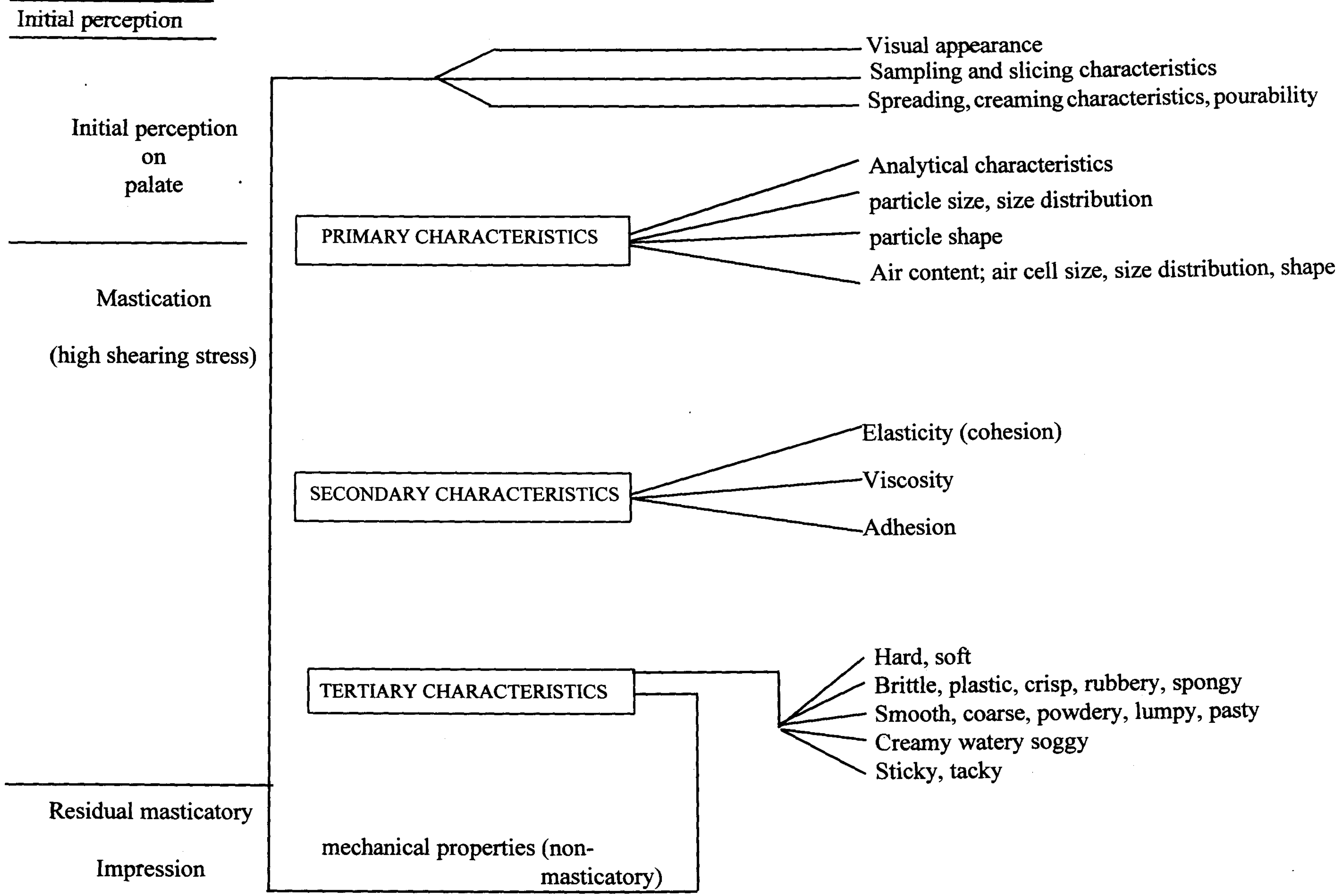

Fig. 1 The texture profile (Sherman 1969)

measurement of texture of variety of food and food products (Voisey 1979; Timbers and Viosey 1987). Many instrumental devices as Allo-Kremer shear press, general food texturometer, Ottawa texture measuring system, universal food rheometer and Instron Universal testing machine have gained popularity in texture assesment (Voisey 1979). Modern developments, specially the test cells holding the sample, transducers (devices to convert forces and deformation into electrical signals for recording) and microprocessor controls have been greatly developed. Versatality, flexibility, accuracy and sampling design features resulted a wider applicability in food texture assessment (Timbers and Voisey 1987). Bourne (1968) measured the texture profile of pears by Instron and subsequently this technique was applied by many workers (Breene 1975; Gupta *et al.* 1984; Green *et al.* 1985; Desai 1988; Pal 1994).For food texture investigations, parallel plate unaxial compression using Instron to obtain force-deformation curve is commonly used (Olkku and Sherman 1979). The food sample, either cylinder or cube, is deformed at a constant deformation rate and mechanical parameters are quantified from the force-deformation curve (Peleg 1987)

2.4.1. Test conditions

The inconsistency of instrumental texture profile analyses depends on the size of the largest unit, shape, homogeneity of structures and composition (Breene 1975). Several workers (Sherman 1976; Vernon *et al.* 1978; Lee *et al.* 1978; Chen *et al.* 1979; Gupta *et al.* 1984; Green *et al.* 1985; Casiraghi *et al.* 1985; Shinin 1987) studied the effects of different test conditions on cheese. The magnitude of response to various test conditions, particularly temperature, varied according to the type of cheese (Lee *et al.* 1978).

2.4.1.1. Sample size and shape

Theoritically, the stress-strain relationship in uniaxail deformation in a perfect test on an ideal material ought to be independent of the specimen dimensions. This could be achieved when height-width or height-diameter ratio is about unity or less. Though standard size cubes, cylinders, discs or rectangular shaped samples have been used for compression' cylindrical or cubical samples with flat surface is most common. The size of compression unit also varies with the sample (Breene 1975).

The Instron texture profile analysis of churpi samples was done by using cubical shaped (5mm x 5mm x 5mm) samples by Pal (1994).

2.4.1.2. 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 two bites. While most workers have used 75-80% compression, a range of 10-90% compression was used by Shama and Sherman (1973a,b). Fracturability is almost independent of the degree of compression, but hardness, cohesiveness, gumminess and chewiness usually increase widely with the increase of compression (Bourne and Comstock 1981). Using double cycled compression, a compression to the magnitude of 25, 50 and 70% was applied (Shinin 1987) to flat, cylindrical test samples of cheese. The result was the significant variation in springiness, chewiness and adhesiveness with the level of compression. To estimate the effect of percent deformation on fracturability, variety of cheese was most important. Acceptable levels of variations were noted when cheese texture was evaluated under levels of strains that did not greatly exceed the fractures or yield value of the cheese. The non-destructive small strain test is also much valuable coupled with the fracture of critical importance in many foods (Mohsenin 1977; Mohsenin and Mittal 1977).

2.4.1.3. Crosshead speed

The crosshead speed has usually been selected at random and ranged from 0.2 to 0.5 cm/min for food (Shama and Sherman 1973 a,b). Pal (1994) applied a crosshead speed of 50 mm/min with chart speed of 250 mm/min for Instron texture profile analysis of churpi.

2.4.1.4. Temperature

The rheological properties of a food sample may change with environmental conditions, such as temperature and moisture (Finney 1969; de Man 1980). While a temperature of 15°C was used in developing a rheological model for paneer (Awadhwal and Singh 1985), the temperature of 30°C was used for Instron measurements of khoa (Gupta *et al.* 1990) and 15° for churpi (Pal 1994)

2.4.1.5. Number of bites

Shama and Sherman (1973 a,b) obtained the hardness using only one bite. Breene (1975) observed that one bite is sufficient to quantify values for brittleness and hardness, and two bites are necessary only when all the parameters of texture profile analysis (TPA) are desired.

2.5. Sensory measurement of food texture

Texture is basically a sensory attribute perceived as a response to different kinds of physical and physio-chemical stimuli (Peleg 1983). No instrument can perceive, analyse, integrate and interprete at the same time a large number of texture sensations. Because of these limitations sensory evaluation of texture profile is extremely valuable. Sensory evaluation is made by the pleasure centre in the brain and provides important information, either analytical or objective, and psychological reaction to the product (Larmond 1976). A detailed account of the basic principles of sensory evaluation, sensory panels, testing environment, sample preparation, method of presentation, sensory methods, sensory perception and scales of magnitude is available (Amerine *et al.* 1965; Birch *et al.* 1977; Piggott 1984; Jellinek 1985).

2.6. Relationship between instrumental and sensory assessment of food texture

Several attempts were made to measure kinaesthetic properties of certain food by instrument and to draw correlation between them (Bourne 1968; Szczesniak 1975; Moskowitz and Kapsalis 1976; Rajpoot *et al.*1981; Szczesniak 1987; Desai 1988; Pal *et al.*1994). These attempts have met varying degrees of success (Szczesniak 1987). Patil *et al.* (1990) studied psychorheological aspects of khoa and interrelationships between the sensory texture perception and instrumental measurement. It can potentially revolutionize the quality control programme with greater reliability and simplicity.

2.6.1. Interrelationship between Instron texture profile and chemical composition

The relationship between Instron texture profile and chemical composition of a product gives ample information to understand the product characteristics and to develop the traditional products. Significant correlations were obtained between moisture and various Instron texture profile parameters of mozzerella cheese and chhana (Keller *et al.* 1974; Desai 1988). A significant correlation was studied between Instron hardness and different chemical parameters of processed cheese foods (Gupta *et al.* 1984). Gupta *et al.* (1990) indicated the possibility of using a single, relatively simple parameter as an index of the texture profile of the product so as to facilitate the quality control programme.

2.6.2. Mathematical expression of relationships

It is well established that sensory and psychorheological models are important in texture studies. Generally, the sensory models imply a stimulus-organism response design and psychorheological models consist of a mathematical expression relating sensory rheological data to the corresponding mechanical data. These two sets of data are usually considered as output and input, respectively (Drake 1979). Associations between subjective and objective texture measurements may be expressed by graphical or mathematical/ statistical terms. Kapsalis *et al.* (1973) studied the linearity, curve fitting of higher order and transformation of data to obtain linearity of relationship with possible predictions and found correlations with a conclusion that the two variables may be the result of third variable which may be unspecified. Various correlation co-efficients quantify the relation between variables. The Pearson correlation coefficient (r) is mostly used for this purpose. It applies to data which possess at least interval-level scale properties (Moskowitz 1981). Multiple correlation was applied to find out the correlations with a combination of instrumental variables and sensory variables. But it does not give the information of basic relation between the combinations of instrumental data and sensory perception (Moskowitz 1981).

Using regression analysis, one can ascertain the relation itself, beyond developing a measure of relatedness of two variables with the assumption of unilateral casuality (Kapsalis *et al.* 1973). Regression analysis helps the experimenter to (a) select a mathematical equation which is assumed to relate the two variables, and (b) to estimate the parameters of that equation by statistical analysis. Often linear equations, as given below, adequately describe the sensory-instrumental relation (Moskowitz 1981).

$$S = k_0 + k_1X_1 + k_2X_2 + \cdots + k_nX_n \quad \cdots (1)$$

where, S is the sensory response and $X_1 \ldots\ldots X_n$ are the intensities of physical variables. In other instance, better fitting equations are developed with a non-linear combination of physical variables. Some of the possibile equations are given below:

$$S = k_0 + k_1X_1 + k_2X_2 + k_3X_1X_2 + k_4X_1^2 + k_5X_2^2 + \cdots \quad (2)$$

$$S = k_0 + k_1X_1 + k_2X_2 + k_3(X_1/X_2) + \cdots (3)$$

$$S = k_0(e^{k_1x_1} + e^{k_2x_2} + \cdots + e^{k_nx_n} \cdots (4)$$

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

The logarithmic function is often used to relate physical intensity to subjective magnitude. The equation is described as

$$S = k \log (I) + C \quad \cdots\cdots (5)$$

where, S is the subjective magnitude and I is the physical intensity. This equation expresses that a ten-fold increase in physical intensity (I) produces a k unit additional increase in the sensory rating (Moskowitz 1981).

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

$$S = k\, I^n \quad \cdots\cdots\cdots (6)$$

where, S is the sensory intensity, I is the physical intensity, k and n are parameters computed from the data (Kapsalis and Moskowitz 1979).

The power function becomes a straight line after a simple transformation

$$\log S = n \log I + \log k \quad \cdots\cdots (7)$$

Moskowitz (1981) suggested a multi-step approach to inter-relating hedonic performance judgement and instrumental measures involving three steps: (1) development of linear or power equations which relate sensory to instrumental measures, (2) development of quadratic equations relating performance ratings, and (3) development of a combined equation.

Subjective-objective interactions for the food industry suggest a multi-stage process: (1) selection of an appropriate subjective attribute, (2) selection of an instrument measure or set of measures that produces sensory perception, (3) hypothesize equations relating subjective and instrumental variables, (4) estimation of parameters of that equation by least square procedure, and (5) estimation of goodness of fit and function to the actual data by means of correlations and F ratios (Moskowitz 1981).

2.7. Texture of dairy products

Davis (1937) made an attempt to relate textural parameters of cheese, as judged by a panel, to rheological properties. This work was considered the basis for defining the quality of foods. Hardness, springiness, smoothness, crumbliness, firmness, stickiness, and sliceability are the textural characteristics of cheese. The effect of chemical and sensory characteristics on textural properties of food were worked out by different workers (Lee *et al.* 1978; Shinin 1987). Processing or storage conditions affect the physical properties of cheese, which in turn, affect its textural characteristics.

Chhana of fine texture velvety with body is considered desirable (Warner 1951; Roy and Dey 1953). Texture of chhana of varying quality, in general, has been described using arbitrary terms as moist, creamy and greasy for visual attributes; scale terms, as soggy, soft, velvety hard for body characteristics and smooth, fine, coarse and granular for texture (Davis 1940; Roy and De 1953; De and Roy 1954; Singh and Ray 1977; Gera 1978; Ahmed *et al.* 1980; Soni *et al*,1980; Bhattacharya and Desraj 1980; Kumar and Srinivasan 1982; Sen and De 1984; Sen 1986). Rheological properties of market quality chhana and the relationship of subjective and instrumental texture data were studied by Desai (1988).

Paneer, a heat-and-acid coagulated milk product, should have optimum firmness to permit easy cutting and slicing, and yet be tender enough so as not to resist crushing during mastication. It should also be compact, smooth and velvety in nature (Patil and Gupta,1986).

Instron hardness, springiness, gumminess and chewiness of the acid-coagulated soyabean curd were greater than those of the salt-coagulated curd. However, cohesiveness remains same in both the cases (Vijayananda *et al.* 1989). Churpi, a light amber to dark brown coloured cubical or cylindrical masticatory, has a very hard and compact body. The interesting characteristics of churpi are its pronounced gumminess and chewability (Pal *et al.* 1993).

2.8. Methods of production of kachcha churpi and churpi

Mainly three types of churpi, namely kachcha churpi, churpi and dudh churpi are available (Tamang 1993). So far, there is no documentation on method of production of dudh churpi.

Traditionally, milk or dahi from milk of cow or yak is defatted, heated to boiling, coagulated and drained. The coagulum is known as kachcha churpi (Pal *et al.* 1994).

Chura, a fermented milk product, is traditionally prepared by heating yak's milk, separating curd by filtration through a cloth, moulding into rectangular (20-40 cm x 15 cm x15 cm) loaves and fermenting ,for several days at room temperature. The sliced loaves are strung on yak hair twine and allowed to sun dry (Batra and Millner 1976).

Karki (1986) described the method of preparation of churpi or durka. Yak milk is fermented under natural condition and curdled by lactic acid production. The butter is separated by churning. The coagulated butter milk is filtered through a cloth and allowed the water to drain slowly. The cloth bag is then closed by sewing all the sides and left for a few days. The solid material is cut into big pieces after taking out from bag. The churpi pieces are allowed to dry over wood-fired oven or under shade.

Tamang *et al.* (1988) also reported the method of preparation of churpi. The cow or yak milk is seperated by centrifugation and the skim milk is boiled and curdled by adding whey. The casein obtained after filtration is wrapped tightly with a cloth and cured at room temperature (15-20°C) for 2-3 days under pressure of approximately 0.25 kg/cm^2 made with the aid of heavy stones. The cheeses are sliced and allowed to sundry for 2-3 weeks. Katiyar *et al.* (1991) reported a method similar to that by Tamang *et al.* (1988). However, in the former, whole milk is used and the period of sun drying is 3-4 weeks.

The methods of preparation of churpi were surveyed in the district of Darjeeling, Sikkim and Bhutan (Pal *et al.* 1993). In Sikkim and Bhutan, the green curd is cooked until free moisture disappears. In Darjeeling hills, the cooking step is omitted. A better quality product is obtained because of cooking.

2.9. Different process parameters

Cow milk with 4.0% fat and 8.6% solids-not-fat (SNF) produced chhana highly suitable for sandesh and rasogolla (De and Ray 1954). Bhattacharya *et al.* (1971) standardized buffalo milk to 6.0% fat and heated to 82°C for 5 min and then cooled to 70°C. The heated (70°C) solution of 1% citric acid was added slowly to get the good quality paneer.

The process conditions in manufacturing churpi were optimized (Pal 1994). Best quality churpi was prepared when cow milk with 1% fat and 8.7% SNF was coagulated at 70°C with 2% citric acid solution, strained immediately, cooked for 20 min in a boiling water bath, pressed the coagulum under 9 kg/cm^2 pressure for 12 h and dried over wood-fired oven for 40-50 days.

2.10. Cooking

The cooking step in the manufacturing different milk products is of utmost importance. Various dhals and grains are also cooked to improve their nutritional and rheological qualities. Cooking quality of legume affects the final acceptability, and the firmness of cooked cowpea was found to be influenced by soaking time and cooking condition (Bakr and Gawish 1992). Cheese curd is cooked with the objective of contraction of curd particles, effective removal of whey and developing a proper texture (Carini *et al.* 1988).

Kneaded chhana balls are boiled at 90-100°C for 20-22 min, and it is one of the main processing steps to get the acceptable quality of rasogolla (Tambet *et al.* 1992). Raw paneer is deep fat fried before being cooked along with vegetables. These processes of frying and cooking are believed to influence the body and textural properties of raw paneer. Many workers (Arora and Gupta 1980; Chawla *et al.* 1985; Sachdeva and Singh 1987) have evaluated the effect of frying and cooking on body and texture of raw paneer.

Deep frying of paneer at 175°C for 4-5 min led to compaction of the paneer structure and also the individual protein particles. However, cooking of the fried paneer by boiling in 1.5% salt solution for 5 min resulted in partial restoration of the overall structure of paneer and ultrastructure of protein particles (Kalab *et al.* 1988).

2.11. Drying characteristics of some foods

Drying is one of the oldest methods of preservation of fruits and vegetables (Videv *et al.* 1990). Drying as the technique of food preservation was achieved using solar energy until the turn of the 20th century, and mechanical drying began to replace natural drying thereafter. Innovation of novel techniques and developments is taking place constantly in existing methods of drying - the ultimate aim of which is to keep wholesomeness in the final product (Chaudhuri *et al.* 1993). The drying involves air drying, vaccum drying and freeze drying. It has been observed that the flavour retention in case of osmovac drying (osmotic dehydration and vacuum drying) is more that than in freeze drying (Choudhuri *et al* 1993). Nambudri (1963) reported that drying temperature above 80°C develops stress cracking of nut. Hence a gradual increase in temperature from 40 to 60°C has been recommended. In case of mechanical dryer where hot air is forced over the material surface, temperature reaches to hot air temperature which results in stress cracking. In case of natural convection dryer, the surface heating is also gradual as that of moisture diffusion from centre to the surface (Patil 1989). Bhandanla and Shah (1989) reviewed the drying behaviour of casein. Drying of casein is a heat and mass transfer process involving variation in modes of heat transfer in different types of dryers. When a material is exposed to drying air, the drying proceeds at a constant rate up to a critical point beyond which the rate is reduced and finally reaches to an equilibrium. The equilibrium moisture content of materials depends on the nature of product and the drying conditions employed.

The principle of casein drying was put forward by Kajda (1970). Kutsakova and Demidov (1980) proposed a mathematical model of drying process for the drying of casein to 18% moisture with air at room temperature in drum type dryers based on heat calculations. Espie *et al.* (1982,1984) studied the drying characteristics of various types of casein curds having different particle size. According to Al'tshultor *et al.* (1977,1978), the best drying conditions were at 0.12-0.16 m layer thickness and 3-6 m/s air velocity in case of aerodynamics for casein drying.

Bhanumurthi and Bansal (1979) reported that drying process was characterized by falling rate of drying as a function of moisture content of casein. Gupta (1989) recommended that 0.9 to 1.1 kg curd of casein should be spread evenly on 75 cm X 75 cm trays at an optimum temperature of 52-57°C.

Four levels of drying air temperatures (60, 70, 80 and 90°C), all at 3.1 m/s air velocity (minimum velocity required for fluidization), were used in fluidized bed dryer. The selection of the air ~~velocity~~ was governed by the fact that the drying air velocity had no effect on drying rate (Uckon and Ulku 1966).

Patil and Shukla (1990) studied the sundrying of blanched soybean and soysplits at different spreading densities of 3.25 kg/m^2, 6.5 kg/m^2 and 9.8 kg/m^2 after blanching the samples for 40 min in boiling water. The variation in moisture content was monitored by the formula:

$$Q_1(100 - M_1) = Q_2(100 - M_2) \quad \cdots\cdots(8)$$

where, Q_1 and Q_2 are initial and final weights in g and M_1 and M_2 are moisture contants on weight basis at Q_1 and Q_2.

The rate of drying (the value of equilibrium moisture content, M_e) was determined using the Chung's equation:

$$M_e = B - C \ln \{-(T+A) \ln RH\} \quad \cdots\cdots(9)$$

where, A, B and C are the coefficients of constants.

The relation was expressed as:

$$MR = (M - M_e)/(Mo - M_e) = e^{kt}$$

They developed the exponential eqnation for different spreading densities and drying performances were indicated by 1st and 2nd falling rate.

Muthu and Chattopadhyay (1992) expresseed the moisture ratio in terms of drying time and drying air properties like temperature and RH in different forms of thin layer drying using Page's model:

$$MR = (M - M_e)/(M_o - M_e) = \exp [- Pt^Q] \quad \cdots\cdots\cdots(10)$$

where, constants P and Q are found to depend upon temperature and relative air. T is air temperature (°C), RH is relative humidity of air %, M is moisture content of grain (db), M_o is initial mositure content (db), M_e is eqnilibrium moisture content (db) and t is drying time (min).

2.12. Water activity

Water activity (a_w) is an important property in the manufacture of food system and formulation (Labuza 1974), and is now recognised as an important preservation parameter (Rao 1993). Most chemical reactions and microbiological activities are controlled directly by a_w of the food system (Labuza 1974).

Living processes have a universal requirement for water. The foodstuffs of high moisture content are easily deteriorated by micro-organisms (Scott 1957). All the moisture, one of the ~~constituents~~ of foods, is not available for deterioration of quality. The water is bound partially to specific sites of food e.g. carboxyl group of polysaccharides, amino group of protein etc. Thus, this monolayer moisture content equivalent to the bound water is not available for microbes and chemical reactions (Sperber 1983). It is clear that the state of water rather than total content of water is important as far as microbial proliferation is concerned. This state of water is related to the vapour pressure of food. Greater the proportion of free water present, greater is the vapour pressure (Scott 1957). Thus, if a product is kept in a close container and allowed to equilibrate, the humidity inside will be a measure of the free state of water of the product. The distilled water shows humidity of 100% and all foods show a humidity <100%. A definite correlation between the the humidity of a food and microbial growth was observed by Scott (1957). He expressed, for convenience, the humidity of a food in decimals and called it water activity of food.

Thus, water activity is usually expressed as a decimal value between zero and unity and may be defined as a modified one of relative humidity (RH) - the ratio of the vapour pressure of the water in food to that of pure water at the same temperature.

$$RH = (V'_p/V_p) \times 100$$

$$a_w = V'_p/V_p$$

$$\text{Thus, } a_w = \%\ RH/100$$

where, a_w is water activity, V'_p is vapour pressure of a food, V_p is vapour pressure of pure water and % RH is the equillibrium relative humidity at which food neither gains nor looses water.

Thus, a_w indicates an intrinsic parameter of food system and relative humidity - a property of surrounding atmosphere in equilibrium with the food system under consideration. Much of the research was focussed on a_w-microbial growth-toxin production relation. Recently, the indepth research has been conducted with regard to microbial, chemical and textural relations of a_w (Scott 1957; Labuza 1970; Rockland and Stewart 1981; Simatos and Multon 1985; Webster *et al.* 1985; Martinez *et al.* 1986; Rockland and Beuchat 1987; Whittenbury *et al.* 1988; Leistner 1992).

2.12.1. Sorption phenomenon

Knowledge of the relationship between food composition, water content and

a_w was formalized by Scott (1957). Foods kept at different humidities absorb or desorb moisture depending on their a_w (Kapsalis 1987). When a_w is less than the surrounding humidity, the product will absorb and when reverse is the case, it will desorb moisture. Therefore, when a product is equilibrated at different humidities it will have different moisture contents. In other words, the product will have a_w's corresponding to the humidities. The water content in the product on solid basis plotted as a function of humidities gives the sorption isotherm of that product. A product with high a_w kept at different lower humidities desorbs moisture, and the corresponding isotherm is called desorption isotherm. But when the same product is dried and equilibrated at different humidities, it absorbs moisture, and the corresponding isotherm is called adsorption isotherm.

The advantages of establishing isotherms of foodstuffs are:
(1) at any given moisture content and temperature the water activity of a product can be calculated; (2) it is possible to estimate bound water, capillary water and multilayer water; and (3) thermodynamic properties of the food, such as enthalpy, Gibb's free energy and heat of sorption can be computed.

Thus, water vapour isotherm is a fundamental characteristic of food materials. It provides necessary insight into the sorption characteristics, drying phenomenon (Kinsella and Fox 1987) and an easy way to evaluate physical, chemical and microbiological parameters suitable for the determination of stability of dehydrated foods (Loncin *et al.* 1968; Labuza *et al* 1970; Mizrahi and Karel 1977). Sorption isotherm can be classified into type I, II and III according to B.D.D.T. (Brunauer-Deming-Deming-Teller) classification (Brunauer *et al.* 1940). Generally, most food stuffs show type-II isotherms (Iglesias and Chirife 1982). Sorption isotherms of several food products including whey proteins, casein, lactose, whey powder, milk powder, cheese and yoghurt have been establised (Wolf *et al.* 1973; Ruegg *et al.* 1974; Saltmarch and Labuza 1980; Berlin 1981).

2.12.2. Equations for describing isotherms

It is well established that no unique mathematical model, either theoretical or emperical, describes accurately the sorption isotherm in the whole range of a_w (0.01 to 0.99) for different types of food. Food is of complex characteristics. Thus, the relation is not linear but sigmoidal. However, the equations are helpful in a limited range of a_w. These equations are generally known by the name of their proposers and are critically reviewed by Chirife and Iglesias (1978) and Boquet *et al.* (1978). Most of the equation generally gives the emperical relationship of a_w to moisture content. But, theoretical equations like Branauer-Emmett-Teller (BET), Langmuir and Guggenheim-Anderson-de Boer (GAB) describe the relation in terms of valuable constants like monolayer and multilayer moisture contents and heat of sorption.

The Halsey equations gives best description of the experimental data followed by the Khun one for milk products and the Mizrahi equation gives fair representation of dairy products (Boquet *et al.* 1978). GAB equation was found to be best-fit model for khoa (Sawhney *et al.* 1989).The monolayer moisture content of khoa was found to be 2.6169 g per 100 g solids, but it increased to 2.7467, 2.7574 and 4.0375 g/100 g solids when 2,4 and 6% glycerol was added to khoa indicating that addition of humectants increases the bound water which is unavailable for micro-organisms. (Sawhney *et al.* 1991a) and when sugar was added to khoa to form pedha the monolayer moisture content increased to 8.73 g per 100 g solids (Biradar *et al.* 1985). The monolayer values (BET) for casein, skim milk powder and chhana powder were observed as 0.049, 0.024 and 0.019 g per 100 g solids respectively (Bandyopadhyay *et al.* 1987). The GAB equation was found to be suitable to predict equilibrium moisture content of paneer upto a_w of 0.90. However, Mizrahi equation, when modified to quadratic form, was found to be suitable in full range (a_w 0.11 to 0.97) (Rao 1993). Using the BET equation, Heldman *et al.*(1965) calculated monolayer moisture content of high heat, medium heat and low heat non-fat dry milk at 16 °C as 11.34, 10.00 and 9.30 g per 100 g solids, respectively. For whey powders, Berlin *et al.* (1973) found a bound, unfreezable water content of 45-52 g per 100 g protein. The monolayer water contents for caseins ranged from 5.06 to 6.18 g per 100 g (Ruegg *et al.* 1979). Washed lyophilized casein micelles isolated by centrifugation gave a typical sigmoidal sorption isotherm upto a_w 0.70, but did not show sharp increase in water uptake between a_w 0.75 and 0.95, normally observed with dried milks and sodium caseinate (Berlin *et al.* 1968).

The monolayer moisture content depends on temperature at which the isotherm was established. In general, monolayer values decrease with increasing temperature of equilibration. This may reflect structural differences with fewer polar sites being available at higher temperatures. The Clasius-Clapeyron model by which equilibrium moisture contents could be calculated for any given a_w and temperature was used by Sawhney *et al.* (1991b) to derive temperature dependance equations for khoa. They also derived equations for predicting a_w when propylene glycol was added to khoa in the range of 0 to 8% (Sawhney *et al.* 1991c).

Different parameters of food like surface area, composition, the number of surface binding sites and the porosity of protein particles influence the thermodynamic property. The number and size of pores in the protein matrix determine total sorption area and the size, and surface properties of the pores influence the rate and extent of hydration (Kapsalis 1981). As water is adsorbed, changes occur specially around 10% water corresponding ,to BET monolayer where available surface area rapidly decreases (Berlin 1981). This may reflect conformational changes in the macromolecule of casein (Kinsella and Fox 1987). The surface area is generally calculated by the equations given by Heldman *et al.* (1965) and Caurie (1981). The surface areas are reported to the values of 238 to 354 m^2/g for various milk powders (Heldman *et al.* 1965), 114 and 127 m^2/g for freeze dried beta-lactoglobulin and serum albumin respectively (Caurie 1981). As high a value as 1200 m^2/g for casein and 800 m^2/g for cheese has been reported by Geurts *et al.* (1974). Rao (1993) found that the surface area of raw paneer, during adsorption, reduced from 124 to 98.69 m^2/g as the temperature increased from 15 to 45 °C.

The pore size distribution of Bologna meat product ranged from 0.26 to 2.77 nm (Igbeka and Blaisdell 1982) and 0.40 nm at 15 °C to 0.44 nm at 45°C for 0.5 g moisture per 100 g solids for paneer (Rao 1993). Thus, the pore size increased with increasing a_w and temperature.

2.12.5. Humectants

Humectants are those compounds which bind free water and decrease a_w of a solution or product. The humactants when added to a food should not affect its organoleptic qualities and should be stable, non-volatile, highly soluble in water, chemically inert, edible in large quantities and, if possible, metabolized *in vivo* as a source of energy (Ledward 1985). Ideally, no humactants, so far studied, fulfill all the requirements. Even though, additives, like salt, sugar and glycerol are now in use as humectants.

2.13. Smoking

Smoking has long been recognised as an important process in the production of meat products. The intensity and duration of smoking are significant in determining the product quality (Smith 1981). Luck *et al.* (1984) fumigated dairy products including milk powder at an average concentration, exceeding 1 g/m^2 for 5 days. They observed that the flavour and appearance of fumigated milk powder were normal. In Ethiopia and other East African countries, Qwanta is prepared by smoking long strips of beef muscle, coated with a mixture of salt, hot pepper and other spices and then frying in butter fat. Khundi is produced in Nigeria by smoke-drying fresh beef, camel or horse meat. This meat is cut into pieces, sprinkled with salts and smoked over hard wood on a grill for about 3 days until it is well smoked. It is storable for several months without refrigeration (Leistner 1990).

2.14. Hurdle concept

The hurdle effect is an illustration of the fact that in most foods several factors (hurdles) contribute to stability and safety. This hurdle effect is of fundamental importance for the presservation of food, since the hurdles in a stable product control microbial spoilage and food poisoning as well as the desirable fermentation (Leistner 1992). Some traditional products are shelf stable. In the field of food preservation, various process parameters such as heating, chilling, freezing, freeze drying, curing, salting, sugar addition, acidification, smoking, oxygen removal etc. employ a few preservation parameters like a_w, pH, high temperature, low temperature (t),redox potential, preservatives, etc. which are called hurdles. Each preservation process may have one or two main hurdles and a few additional hurdles (Table 2).

Hurdle technology is by no means a new preservation process, since mummification in ancient Egypt could be viewed as an old example of meat preservation by hurdle technbology. The hurdles may be defined as obstructions to microorganisms, and microorganisms overcoming the hurdles have been allegorised to jumping the hurdles. The crux of hurdle technology principle

Table 2. Processes used in food preservation and parameters or hurdles based thereon*

Parameters	Processes						
	Heating	Freezing	Drying	Salting	Acidification	Smoking	Intermediate-moisture
High temp. (F)	x	*	*	0	0	*	*
Low temp. (t°)	*	x	o	*	*	*	*
Water activity (a_w)	*	x	x	x	o	*	x
pH	*	o	*	*	x	*	*
Redox potential (Eh)	*	*	o	*	*	*	*
Preservatives	*	o	*	*	*	x	x
Competitive flora	o	o	o	o	*	o	*

x, main hurdle; * additional hurdle; o not important

*Adapted from Leistner *et al.* (1981)

is that each hurdle in a food is used at sublethal level. Three or more hurdles together will have a lethal effect just sufficient to preserve the food.

Leistner (1992) classified the shelf stable products (SSP) as F-SSP, pH-SSP, a_w-SSP, combi-SSP depending upon the major hurdle used in its preservation. The primary reason for stability of F-SSP is the inactivation or sub-lethal damage of bacterial spores due to sub-lethal heat treatment, for a_w the reduction of a_w, for pH-SSP an increased acidity, and in combi-SSP several hurdles are balanced out. Several traditional SSP's have been marketed for many years. But literatures on this aspect on dairy products are scanty. Some dairy products are traditionally manufactured and later on developed to make shelf stable. Chhana is less stable, but rasogolla made out of it is more stable.

When paneer cubes were immersed in brine solution, the keeping quality is increased to 20 days due to the effect of brine (Sachdeva 1983). It was possibly due to the effect of pH and a_w. Paneer with limited shelf life of two days was developed by applying mild heat treatment in cans with desirable sensory characteristics. It is storable for several weeks without refrigeration in cans (Rao *et al.* 1992). Cheese whey concentrate could be made shelf stable for 3 months at 30°C by combining a_w, pH and sorbate at a level of either 0.94, 5.2 and 0.2% or 0.92, 5.4 and 0.2 %, respectively (Dekanterwicz *et al.* 1985).

2.15. Preservatives

Preservatives are the chemical compounds or mixtures of compounds for the specific purpose of preventing spoilage due to growth of bacteria, yeasts or moulds. There are two categories of microbial antagonists useful in food preservation. They are either inorganic or organic in nature.

2.15.1. Potassium sorbate

Sorbic acid and its potassium or sodium salts are of wide application as preservatives. They are used generally in wine making, baking and cheese products. These substances have been permitted in food products as chemical preservatives according to the Indian Prevention of Food Adulteration Rules.

The addition of potassium sorbate in khoa is an additional precaution to enhance its keeping quality which is helpful under commercial condition (Ghodekar *et al.* 1978). Potassium sorbate is extensively used to extend the shelf life of khoa (Jha *et al.* 1977; Kumar and Srinivasan 1982), chhana (Kulkarni *et al.* 1984), paneer (Rao 1993) and cheese (Kulkarni *et al.* 1968; Moustafa and Collins 1969). Growth of moulds on the surface of foods such as cheese was prevented by the application of potassium sorbate (Marth *et al.* 1966).

2.16. Packaging and storage of food products

Packaging is a vital tool for popularization of any new, imitation or traditional food products. Both fresh and processed foods need packaging to maintain their quality and reduce wastage during storage and distribution caused by physical, chemical and biological factors (Anandaswamy *et al.* 1962; Dani *et al.* 1969). Mathur (1991) advocated the scientific effort for finding out the suitable packaging system for upgradation of traditional milk products.

3. MATERIALS AND METHODS

3.1. REAGENTS USED

Ammonium molybdate solution

6% w/v $(NH_4)_6Mo_7O_{24}.4_2O$ in distilled water

Barium chloride solution

9.88% w/v $BaCl_2$ in distilled water

p-Dimethylaminobenzaldehyde solution

4% w/v p-dimethylaminobenzaldehyde in chloroform

Fehling's solution A

34.639 g of $CuSO_4.5H_2O$ was dissolved in distilled water and diluted to 500 ml.

Fehling's solution B

173 g of potassium sodium tartrate and 50 g of NaOH were dissolved in water, diluted to 500 ml and filtered.

Ferric chloride solution

10% w/v $FeCl_3.6H_2O$ in distilled water - used the fresh preparation

Glycine-sodium hydroxide buffer

150 ml solution containing 2.4768 g glycine and 1.9359 g NaCl was mixed with 850 ml 0.385 N NaOH and pH was adjusted to 12.8.

Methylamine solution

5% w/v methylamine-HCl in distilled water

Mixed indicator solution

One part of 0.2% w/v ethanolic methyl red was mixed with five parts of 0.2%

w/v ethanolic bromocresol green.

Phenol reagent

To the reagent prepared according to Folin and Ciocalteau, two volumes of water were added.

Phosphate-phthalate buffer

0.3 g KH_2PO_4 and 5.1 g potassium acid phthalate were dissolved in 158.1 N NaOH and diluted to 250 ml the pH was adjusted to 5.3. A few drops of toluene were added.

Sodium carbonate-sodium tetraphosphate solution

75 g anhydrous Na_2CO_3 and 10 g sodium tetraphosphate were dissolved in water and diluted to 500 ml.

Sodium hydroxide-sodium thiosulphate solution

60 g NaOH and 5 g $Na_2S_2O_3$ were dissolved in distilled water and diluted to 100 ml.

Sodium sulphite solution

1% w/v Na_2SO_3 in distilled water

Standard invert sugar solution

1.1875 g of dried sucrose was transferred to a 500 ml flask with 75 water. 10 ml of 6.34 N HCl was added slowly while rotating the flask. The flask was immersed for 5 min in a 70°C water bath and cooled immediately to 20°C. The solution was made neutral to litmus with N NaOH solution and the volume was made to 500 ml at 20°C.

1 ml = 2.5 mg invert sugar

TBA reagent

0.67 g 2-thiobarbituric acid was dissolved in 75 ml glacial acetic acid. 2 ml concentrated HCl was added in it. Final volume was made to 100 ml with distilled water.

Zinc acetate-phosphotungstic acid reagent

25.0 g zinc acetate and 12.5 g phosphotungstic acid were dissolved in distilled water. After addition of 20 ml glacial acetic acid, the mixture was distilled to 100 ml.

Zinc sulphate solution

22.5% w/v $ZnSO_4.7H_2O$ in distilled water

All the chemicals used in this study were of the highest purity grade.

3.2. EXPERIMENTAL

3.2.1. Survey on dudh churpi

A survey was conducted in the villages of Bhutan, Sikkim and Darjeeling to collect information on the types, traditional methods of preparation, modes of consumption, cost of production and market prices of dudh churpi (Fig. 2).

3.2.2. Collection of market samples

Dudh churpi samples were purchased from different shops of Phuntsholing (Bhutan), Gangtok (Sikkim) and Darjeeling (West Bengal). The samples were kept in clean stainless steel containers with tightly closed lids. They were

Fig. 2. Market samples of dudh churpi

transported immediately to the laboratory for analyses.

3.2.3. Physico-chemical analyses of market samples of dudh churpi

3.2.3.1. Reflectance

A reflectometer (Elico, type CL-28, India) with magnesium block (which gives 100% reflectance) was used to measure the colour of dudh churpi (Pal 1994).

3.2.3.2. Chemical analyses

Samples of dudh churpi were broken into small pieces and then powdered using a grinder (Bajaj, India)

3.2.3.2.1. Moisture

Moisture content in dudh churpi was determined by gravimetric method (AOAC 1990). A sample of ground dudh churpi (*ca* 2 g) was weighed into a cooled and weighed tared dish, previously heated to 130$\pm$1 °C. The sample was dried for 1 h at 130 $\pm$ 1°C. The dish was covered while still in oven, transferred to a dessicator and weighed soon after reaching room temperature. The process of drying, cooling and weighing was repeated until the two successive weighings reached a constant value. The difference between the initial and final weights was taken as the moisture content.

3.2.3.2.2. Total fat

Total fat content in dudh churpi was determined by the Röse-Gottlieb fat extraction method (ISI 1981) with modification. In a beaker, containing 10 ml of concentrated hydrochloric acid, approx. 5 g (accurately weighed) ground sample was placed and another 10 ml of hydrochloric acid was further added to wet and wash down particles adhered to the sides. The contents were heated over a burner so that all the particles dissolved in the acid. The contents were finally boiled for 10 min and allowed to cool to room temperature (*ca* 25°C). About 10 ml of acid as wash liquid were used to transfer the contents quantitatively to a Röse-Gottlieb fat extraction tube. Twentyfive ml of diethyl ether was added to the beaker, and the contents were transferred to the tube. Again 25 ml of petroleum ether was added to the beaker and transferred to the tube. It was stoppered with a bark cork, shaken vigorously for 1 min and allowed to stand until the upper liquid was clear. The solution was decanted into a preweighed Erlenmeyer flask. The extraction procedure was repeated twice using both the solvents in equal parts. The solvent was evaporated completely on a steam bath and fat was dried in an oven at 100±1°C to constant weight.

$$\text{Fat, \% (w/w)} = (W_2 - W_1)/W_3 \times 100$$

where, W_1 is the weight in g of flask, W_2 is the weight in g of flask with contents of flask after drying, and W_3 is the weight in g of sample taken for the test.

3.2.3.2.3. Free fat

The free fat content of dudh churpi was determined by the following method, recommended for milk powder (Hall and Hedrick 1971). Ten g of ground dudh churpi was taken in a 250-ml Erlenmeyer flask and 100 ml petroleum ether was added in it. The flask was shaken with a vertical motion for 10 times. The contents were allowed to settle for 15 min and filtered through a Whatman No. 42 paper catching the solvent in a tared Mojonnier fat dish. Following the same procedure, a second extraction was also exercised. The etheral layer was evaporated in a hot air oven at 100±1°C and the sample weight was determined:

Weight of sample = W_1 g

Weight of empty fat dish = W_2 g
Weight of fat dish after drying = W_3

Free fat % w/w = $(W_3-W_2)/W_1 \times 100$

3.2.3.2.4. Free fatty acid

The free fatty acid content in dudh churpi was estimated by the method prescribed as per ISI (1966) with minor modifications.
An accurately weighed (*ca* 5 g) ground sample was mixed with 95% ethanol neutralized previously by 0.1 N NaOH, using phenolphthalein (0.01% w/v in 95% ethanol) as indicator. The solution was heated to boiling on water bath and filtered through a Whatman No. 1 paper. The filtrate was titrated with 0.1 N NaOH solution until a pink colour persisted.

$$\text{Free fatty acid \% (as oleic acid)} = \frac{100 \times \text{ml of NaOH} \times \text{N of NaOH} \times 2.82}{\text{weight of sample (g)}}$$

3.2.3.2.5. Total Protein

The total protein content of dudh churpi was determined by the micro-Kjeldahl method as described in IS 4079 (1967). Approximately 1 g accurately weighed ground sample taken in a digestion flask was added with 10 g potassium sulphate, 0.5 g mercuric oxide and 20 ml concentrated sulphuric acid (sp. gr. 1.84, nitrgen free).

The flask was heated gently until frothing ceased, boiled briskly until the solution became clear, and then continued the boiling for about 1 h. The content of flask was cooled to room temperature and made upto the volume in a 100 ml volumetric flask with distilled water. Ten ml aliquot of the solution was transferred to micro-Kjeldahl distillation flask and made the solution alkaline by 8 ml sodium hydroxide-sodium thiosulphate solution. The flask was immediately connected to a distillation apparatus and the tip of the condenser was immersed in a saturated solution of boric acid containing 2-3 drops of mixed indicator solution. The distillation was continued until about 50 ml of the distillate was collected which was then titrated against 0.02 N hydrochloric acid till violet colour appeared. A blank was carried out using all reagents in the same quantities without the material to be tested.

$$\text{Protein, \% w/w} = \frac{89.32\,(V_2 - V_1)\,N}{W}$$

where V_2 = ml of hydrochloric acid used in distillation,

V_1 = ml of hydrochloric acid used in the blank test,

N = normality of hydrochloric acid, and

W = weight of the sample (g) taken for analysis.

3.2.3.2.6. Water-dispersible protein

About 5 g of accurately weighed ground sample was dispersed in about 50 ml warm (40°C) water. The mixture was transferred to a 100 ml volumetric flask and the volume made upto the mark. After mixing thoroughly, the contents were filtered through a Whatman No. 2 paper and nitrogen content in the known volume of the filtrate was determined using the micro-Kjeldahl procedure as described in section 3.2.3.2.5.

3.2.3.2.7. Tyrosine value

Tyrosine value in the product was estimated as per the method given by Hull (1947). One g ground sample was taken in a test tube and 1 ml of distilled water was added, followed by the addition of 0.72 N trichloroacetic acid while agitating the tube to mix the sample. The tube was stoppered, shaken vigorously and allowed to stand for 10 min before filtering the contents through a Whatman No. 42 paper. Five ml of the filtrate was added to a 50 ml Erlenmeyer flask and 10 ml of sodium carbonate reagent was added and mixed thoroughly before 3 ml of phenol reagent was added. The blue colour was measured in a spectrophotometer (Systronics, type 106, India) at 650 nm. A standard curve was prepared to convert the absorbancy into tyrosine equivalent.

3.2.3.2.8. Lactose and glucose-galactose

Lactose and glucose-galactose of the sample were determined by the method as described by Nickerson *et al.* (1976). About 4 g of accurately weighed sample and 1 ml of zinc acetate-phosphotungstic acid reagent and 20 ml of distilled water were added to it. After 10 min, the well-mixed content was filtered through a Whatman No. 1 paper. The filtrate (0.5 ml) and 0.5 ml of 1 N sodium hydroxide were mixed, diluted to 10 mlby distilled water and filtered through a Whatman No. 1 paper. Five ml of the filtrate was mixed thoroughly with 5 ml glycine-sodium hydroxide buffer, 0.5 ml methylamine solution and 0.5 ml sodium sulphate solution. The content was heated in a water bath for 25 min at 65°C and cooled immediately in an ice-water bath. Absorbance was read against blank (using water in place of sample) at 540 nm in a spectrophotometer.

For the determination of glucose-galactose, 5 ml of phosphate-phthalate buffer was mixed thoroughly with 1.0 ml of the standard unknown or water (blank) and 5 ml of ammonium molybate solution. The content was heated in a boiling water bath for exactly 15 min and cooled immediately with tap water to stop reaction. Absorbance was read against blank (using water in place of sample) at 710 nm.

3.2.3.2.9. Total sugar

The amount of sucrose of the product was estimated by Lane-Eynon method (ISI 1967) for canned rasogolla.

A well-ground sample (40 g) was transferred to a 100-ml beaker and 50 ml of hot water at 80 to 90° was added. The well- mixed content was transferred to a 250-ml measuring flask, washing it with successive quantities of distilled water at 60° until the volume was 120 to 150 ml. The contents were mixed well and cooled to room temperature. Five ml of dilute ammonia solution was added in it, and it was kept for 15 mins. An equivalent amount of dilute acetic acid was added to neutralize the added ammonia. Zinc acetate solution (12.5 ml) was added followed by the addition of 12.5 ml of potassium ferrocynide solution. After adjusting the volume to 250 ml with distilled water, the solution was allowed to settle and filter. It was marked as B_1. Fifty ml of

B_1 solution was taken into a volumetric flask, added with 5 ml of concentrated hydrochloric acid and heated at 68°C for 5 min. After cooling, the solution was neutralized and the volume made upto 100 ml. This solution was marked as A_1.

The solutions B_1 and A_1 were diluted so that the volume of solution required for titrating 10 ml Fehling's solution was between 15 and 50 ml. They were marked B_2 and A_2, respectively. Ten ml of Fehling's solution was taken into a 250-ml Erlenmeyer flask and solution B_2 was taken in a 50-ml burette and filtration was completed. In a similar way the filtration was completed for the solution A_2 and sucrose was calculated using the formula:

$$\text{Sucrose \% w/w} = (20W_1/W_2)(2f_2/V_2 - f_1/V_1)$$

where,

W_1 = mg of sucrose corresponding to 10 ml Fehling's solution,
W_2 = g of sample taken,
f_2 = dilution factor for solution A_2 from A_1.
V_2 = volume in ml of solution corresponding to 10 ml Fehling's solution,
f_1 = dilution factor of solution B_2 from B_1 and
V_1 = volume in ml of solution B_2 corresponding to 10 ml of Fehling's solution.

Total sugar expressed as:

Total sugar % = Lactose % + glucose-galactose % + sucrose %.

3.2.3.2.10. Lactic acid

Lactic acid in dudh churpi was estimated by the method prescribed by Harper and Randolph (1960) for cottage cheese. Ten g ground dudh churpi was macerated with 90 ml distilled water for 5 min in a waring blender (Bajaj, India) at high speed. Twenty-five ml of the mixture was pipetted into a 100-ml Erlenmeyer flask. Ten ml barium chloride solution and 5 ml 0.66 N sodium hydroxide solution were added in order and mixed thoroughly with each addition. The contents were filtered through a Whatman No. 40 paper, and 10 ml of the filtrate was taken in a clean dry test tube. Two ml of freshly prepared 1% ferric chloride solution were added and mixed by inversion. The absorbance was recorded in a spectrophotometer (Systronics type 106), at 425 nm against a blank prepared in the same manner replacing dudh churpi with 10 ml cold distilled water. A standard curve was prepared by adding known concentration of lithium lactate to distilled water to convert the sample reading into its lactic acid equivalent.

3.2.3.2.11. pH

A sample (10 g) was mixed with 90 ml carbon dioxide-free distilled water in a waring blender (Bajaj, India) for 1 min. The temperature of the mixture prepared was equilibrated at 25°C and the pH was noted (AOAC, 1990) using a pH meter (Systronics, type 335, India).

3.2.3.2.12. Titratable acidity

About 10 g of ground sample was accurately weighed and blended with 90 ml carbon dioxide-free hot distilled water for 1 min. The mixture was filtered through a Whatman No. 1 paper, and 25 ml of the filtrate was titrated with 0.1 N sodium hydroxide to end point of phenolphthalein (0.1% w/v in 95% ethanol) (AOAC 1990).

$$\text{\% Titratable acid content (as lactic acid)} = \frac{100 \times \text{ml of NaOH} \times \text{N of NaOH} \times 0.09}{\text{Weight of sample (g)}}$$

3.2.3.2.13. Ash

A ground sample (*ca* 3 g) was accurately weighed into a previously dried and weighed silica crucible and placed in a hot air oven at 100±1°C for 1 h. The dried sample was then ashed in a muffle furnance at 550±20 °C for 3 h. The crucible was transferred directly to a dessicator, allowed to cool to room temperature and weighed immediately. The process of heating for 30 min, cooling and weighing was repeated until the difference between two successive weighings was <1 mg. The lowest mass was recorded (ISI 1965).

$$\text{Total ash, \% w/w} = \frac{(W_1 - W)}{(W_2 - W)}$$

where, W_1 = weight in g of the crucible containing the ash,
W = weight in g of the crucible and
W_2 = weight in g of the crucible with the material taken for the test.

3.2.3.2.14. 2-Thiobarbituric acid value

The method described by Sidwell *et al.* (1955) was followed. A well-ground sample of (30 g) dudh churpi was taken in a Kjeldahl flask. Sixty ml water was added and the sample was properly dispersed. Thereafter, 7 ml of 3 N hydrochloric acid was added and mixed thoroughly (the ratio of sample to water was so adjusted as to get the pH of the mixture between 1.5-2.0 after the addition of 3 N HCl). The contents were then distilled collecting 50 ml distillate in about 10 min. Twenty ml of the distillate was pipetted into a 60-ml glass stoppered tube, and to this 2 ml of TBA solution (0.67 g 2-thiobarbituric acid in 100 ml glacial acetic acid) was added. The tube was stoppered, shaken and placed in a boiling water both for 35 min. The contents were cooled to room temperature and absorbance was determined at 530 nm. Blank determinations were made using distilled water in place of sample. TBA value was expressed as absorbance at 530 nm.

3.2.3.2.15. 5-Hydroxymethylfurfural (HMF)

Free and potential HMF were determined by the method recommended by Keeney and Bassette (1959). One g of ground dudh churpi was taken in a 50-ml test tube. Five ml of 0.3 N oxalic acid was added in it and mixed thoroughly. The tube was covered with inverted 20-ml beaker and kept in a boiling water bath for 1 h. The tube was removed and cooled to room temperature with cold water. While estimating free HMF in the sample, this heating step was omitted. Five ml of 40% trichloroacetic acid solution was added in it and mixed thoroughly. The precipitate was filtered through a Whatman No. 42 paper. Four ml of the filtrate was pipetted into a 15-ml test tube and 1.0 ml of 0.05 M 2-thiobarbituric acid solution was added and mixed well. The tubes were kept in a water bath at 40°C for 35 min. The contents of the tube were cooled to room temperature and the absorbance was measured at 443 nm against blank prepared same as sample, substituting water for dudh churpi.

A standard curve of HMF (Sigma, USA) concentration against optical density at 443 nm was made using a stock standard solution (10 μmol) of HMF prepared in distilled water. Further dilutions were made in the range of 1.0 to

10.0 μmol HMF. The dilutions were treated same as sample for HMF estimation. From the standard curve, following regression equation was obtained using which the HMF content in the sample was determined:

HMF (μmol/g) = R X 250.57 - 7.07 (for free HMF)

HMF (μmol/g) = R X 183.67 - 3.06 (for total HMF)

where, R = absorbance

3.2.3.2.16. Para-dimethylaminobenzaldehyde reactivity

The method of Kumar and Hansen (1972) was followed. Two ml of p-dimethylaminobenzaldehyde solution and 4 ml of distilled formic acid were accurately pipetted into a screw-capped test tube. Ground sample (0.1 g) of dudh churpi was added slowly into the reaction mixture. The tube was capped, mixed thoroughly and incubated at 37±1°C for 30 min. The content was then immediately cooled to 5°C and centrifiged at 1000 x g for 10 min. The clear pink supernatant was brought to room temperature and measured for its absorbance at 545 nm against a blank prepared from unheated milk.

3.2.3.2.17. Energy value

The energy value of a sample was estimated by multiplying its percent protein, fat and carbohydrate contents by the factors 4.1, 9.3 and 4.1, respectively and adding all the multiplication values to get kcal (0.239 cal = 1 J) per 100 g (De 1980).

3.2.4. Sensony evalution of dudh churpi

The representative samples of market dudh churpi from Bhutan, Sikkim and Darjeeling as well as laboratory-made dudh churpi were evaluated by seven judges. The panel of judges was constituted on the basis of their interest, performance, motivation, willingness and reliability. The judges were first trained in the assessment of quality attributes and the probable defects in dudh churpi. The samples were presented to the penalist for sensory evaluation using 25-point score card (Table 3), developed for the purpose of product evaluation

The sensory texture profile of dudh churpi was evaluated using a rating scale (Table 4) in the form a 10 cm horizontal dotted straight line with 10 dots where each dot was scored 1. The left end of this scale indicated one parametric extreme (0) and the opposite end indicated the other extreme (10) except for crumbliness where it was just the opposite. Scoring was done by making a vertical line along the scale (10-point) with the respective sample number by indicating the perceived intensity/acceptability.

3.2.5. Instrumental evaluation of dudh churpi

Cubical (5 mm X 5 mm X 5 mm) samples of dudh chupri were subjected to uniaxial compression by 20% of the initial sample dimension using an Instron Universal Testing Machine (Instron Ltd, mode 4301, UK), fitted with a 1000 N load cell. The force-distance curve (Fig. 3) obtained for a two-bite deformation cycle, employing a cross-head speed of 50 mm/min and a chart speed of 250 mm/min, was used to determine various texture profile parameters of dudh churpi at 30°C . The parameters measured were hardness (height of the first peak, A_1, i.e. the maximum force recorded during the first compression cycle; N), cohesiveness (area under curve A_2 area under curve A_1), springiness (width

Table 3. Sensory score card for dudh churpi

Attributes	Defects	Intensity			Samples				
		Slight	Definite	Pronounced	A	B	C	D	E
Flavour (10)	High acid/sour	9	7	3					
	Bitter	7	5	1					
	Rancid	5	3	1					
	Oxidized	6	4	2					
	Stale	8	6	5					
	Mouldy/yeasty	5	2	0					
	Unclean	6	4	1					
	Fermented/fruity	5	3	1					
Body and texture (10)	Rubbery	6	4	2					
	Weak/soft	5	2	0					
	Mealy/grainy	8	6	4					
	Open	8	6	4					
	Soggy	0	0	0					
Colour and appearence (5)	Brown	3	2	1					
	Mouldy	0	0	0					
	Unnatural	1	0	0					
Total score (25)									

Date:

....

Signature of the Judge

Table 4. Sensory evaluation card for texture of dudh churpi

To the panelist:

Kindly evaluate the given samples for different textural properties using the scales given below. To indicate your judgement, make a vartical 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. Smoothness
   Grainy/rough . . . . Extremely smooth

5. Gumminess
   Least gummy . . . . Extremely gummy

6. Chewiness
   Least chewy . . . . Extremely chewy

7. Overall textural quality
   Undesirable . . . . Most desirable

Remarks (if any):

Date:

Signature:
Name :

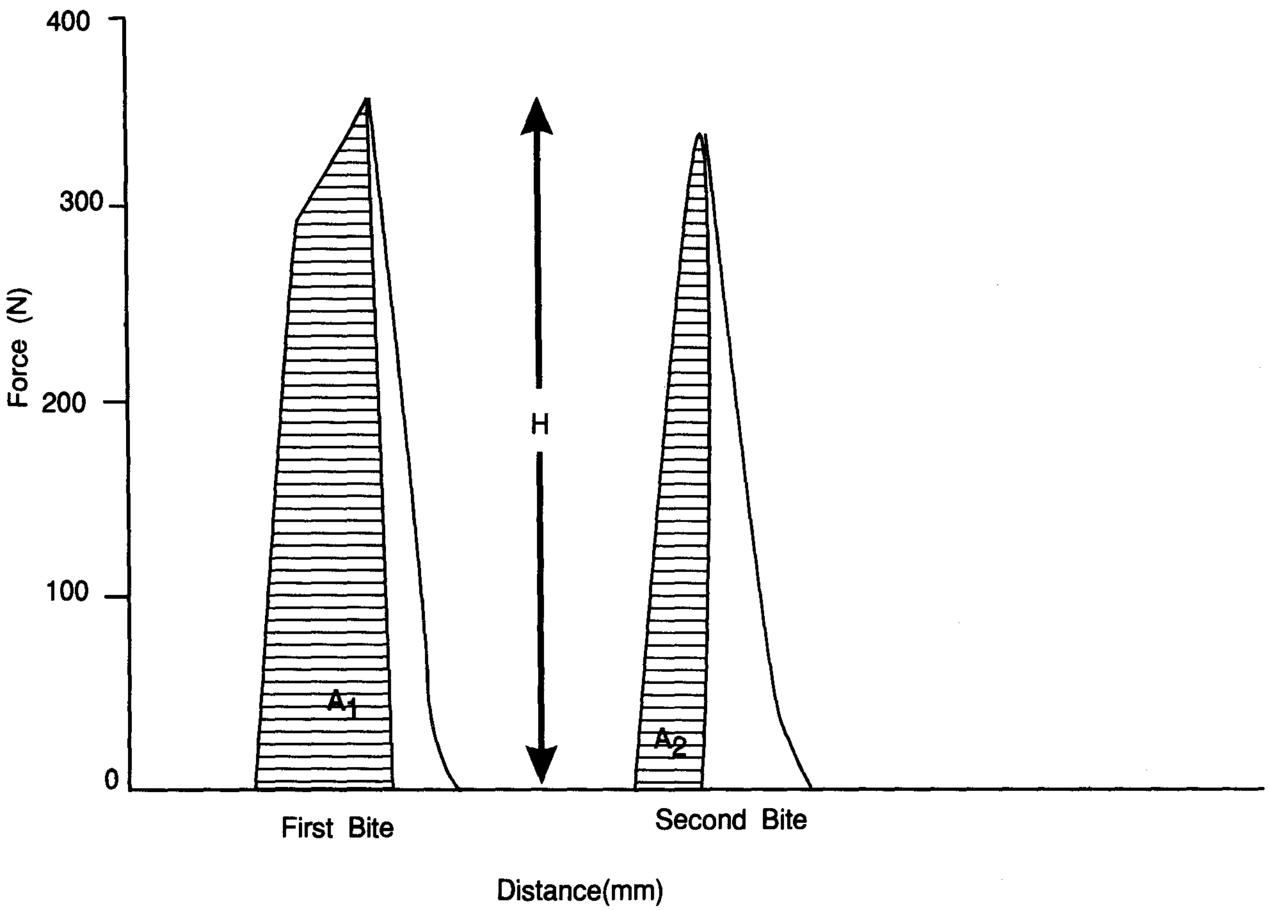

Fig. 3. A typical two-bite force-distance compression curve for dudh churpi

of the downstroke in curve A_2; mm), gumminess (hardness X cohesiveness; N) and chewiness (gumminess X springiness; N.mm) (Brady *et al.* 1985). The values were expressed for total cross sectional area (mm^2) of the samples.

3.2.6. Preparation of laboratory samples

Prechurpi was prepared by the method described by Pal (1994) and the product was developed in the laboratory on the basis of traditional methods.

3.2.6.1. Materials

3.2.6.1.1. Milk

Pooled cow milk was procured from the Himalayan Co-operative Milk Producers Union Limited (HIMUL), Matigara. The raw milk samples (4-5 h-old) had pH of 6.6-6.7, fat content of 3.5-4.0% and total solids of 11.5-12.0%.

3.2.6.1.2. Skimmilk powder

The Skimmilk powder manufactured by the Kaira District Co-operative Milk. Producers' Union Limited, Anand, Gujarat was used for standardization of milk to desired solids-not-fat (SNF) content.

3.2.6.1.3. Coagulant

Citric acid (SD Chemicals, Bombay) was used as a coagulant in desired concentrations.

3.2.6.1.4. Sugar

Commercial cane sugar was used as the sweetening agent in milk.

3.2.6.2. Processing conditions

3.2.6.2.1. Standardization of milk

Cow milk was skimmed by a mechanical cream separator (Kamdhenu, Sinhal Metal Industries, Bombay; capacity, 60 l/h). The skim-milk was standardized to 1% fat and 8.7% SNF by adding fresh cream and skim milk powder. Total solids content was determined with 5 g milk as per the method described in section 3.2.3.2.1. Fat in milk was determined by the Gerber method (ISI 1981). Ten ml of sulphuric acid (density 1.807-1.812 g/ml at 27°C) was taken into a Gerber butyrometer for milk. A well-mixed sample (10.75 ml) of milk and 1 ml of amyl alcohol were added in it. The butyrometer was stoppered and the content was mixed by shaking at an angle of 45° until all the milk solids were dissolved. The butyrometer was kept in a waterbath at 65±2°C for 5 min, centrifuged at 1000 x g for 5 min and again placed in the bath for another 5 min. The fat content was directly recorded from the scale of butyrometer. Titratable acidity of milk was determined by titrating 10 ml of well-mixed sample against 0.1 N sodium hydroxide using 1 ml of 0.5% phenolphthalein as indicator.

3.2.6.2.2. Preparation of prechurpi

3.2.6.2.2.1. Coagulation of milk

Milk was heated to 70°C in a stainless steel container and coagulated using 2% w/v citric acid solution at 70°C. The coagulation was completed within 60 s.

3.2.6.2.2.2. Straining

The coagulum-whey mixture was held for 5 min before the removal of whey through a muslin cloth.

3.2.6.2.2.3. Cooking of coagulum

The coagulated mass, held in a muslin cloth, was transferred to a stainless steel container and cooked with constant stirring, till the disappearance of free miosture followed by the appearance of an oily surface.

3.2.6.2.2.4. Pressing of coagulum

The hot cooked mass was wrapped in a muslin cloth, transferred to a wooden hoop (10 cm x 10 cm x 10 cm) and pressed under 9 kg/cm^2 pressure for 12 h.

3.2.6.2.2.5. Drying of prechurpi

The pressed mass was cut into equal pieces and made a ring with a thread. The rings of prechurpi were hanged over wooden fire at 30±5°C and partially dried to the desired level of moisture.

3.2.6.2.3. Cooking of prechurpi

Prechurpi was cooked for a suitable period with milk of different levels of fat and sugar contents, and condensed to different levels of total solids using a water bath. The prechurpi pieces were then cooked in the standardized and condensed milk by constant stirring. They were cooled to room temperature.

3.2.6.2.4. Drying of dudh churpi

The rings of dudh churpi were dried over wooden fire and also in a drier for different sets of temperature.

3.2.7. Optimization of process parameters

Prechurpi was prepared as per the method given by Pal (1994). In this study, the processes for cooking prechurpi and drying of dudh churpi were optimized.

3.2.7.1. Optimization of cooking media

3.2.7.1.1. Fat level

Skim milk was standardized to different levels of fat (i.e. 0.1, 1.0, 2.0, 3.0%)

and 8.7% w/w solids-not-fat (SNF) using fresh cream and skim-milk powder. Milk was added with 2% w/w sucrose and condensed by boiling to 29.25% w/w total solids. Then, prechurpi was cooked for 15 min and cooled to room temperature. The cooked mass was hanged over a wooden fire for 20-25 days. Dudh churpi, thus prepared, were subjected to various chemical, sensory and instrumental analyses.

3.2.7.1.2. Sugar concentration

Milk standardized to 1.0% w/w fat and 8.7% w/w SNF and added with 0,1,2 and 3% w/w sucrose levels was condensed to 29.25% w/w total solids. Rest of the procedure same as described in section 3.2.7.1.1. The product was subjected to sensory, instrumental and intrinsic analyses.

3.2.7.1.3. Total solids content

Milk standardized to 1.0% w/w fat and 8.7% w/w SNF was condensed to different levels of total solids (i.e. 11.70, 15.60, 23.40, 29.25% w/w) after addition of 2% w/w sugar. Rest of the procedure was followed as described in section 3.2.7.1.1. The product was subjected to sensory and objective analyses.

3.2.7.1.4. Time of cooking prechurpi

Prechurpi was cooked in milk, standardized to 1.0% w/w fat and 8.7% w/w SNF, added with 2.0% w/w sucrose and condensed to 29.25% w/w total solids, for different periods. They were cooled to room temperature. Rest of the procedure was same as described in section 3.2.7.1.1. The product was subjected to objective textural analysis.

3.2.7.2. Moisture level of prechurpi

Prechurpi of equal sizes (4 cm x 2 cm x 1 cm) were dried at different temperatures. The traditional drying was continued over wooden fire. Three different drying chambers maintained at 35, 40 and 45°C were also used and the product was smoked for 30 min with wood charcoal. The traditional drying as well as chamber drying product were dried to 40, 35, 30 and 25% moisture content. The products were cooked in the standardized milk as described in the section 3.2.7.1.4. Further drying was continued under the same previous condition of drying till the product attained a moisture content of 15.4%.

The samples of dudh churpi thus prepared were subjected to sensory alalysis.

3.2.7.3. Drying behaviour after cooking prechurpi

The cooked and pressed mass of coagulum was cut into different sizes and shapes (cylindrical, 2.2 cm x 2.1 cm dia; rectangular, 4.0 cm x 2.0 cm x 1.0 cm and 3.0 cm x 2.0 cm x 2.3 cm). These products were dried to 30% moisture content, cooked and again dried under conditions as mentioned in section 3.2.7.2. The maximum and minimum drying temperatures and relative humidity at different days of traditional drying were recorded. The samples, thus prepared, were subjected to sensory and objective textural analyses.

3.2.8. Packaging and storage

One lot of samples was prepared by incorporating 0.1% w/w potassium sorbate in milk at the time of cooking prechurpi (A). The other lot of dudh churpi was prepared as such (B).

The packaging materials used for storage study were 200-ml glass jar with screw (P_2), 300-µm high density polyethylene container, (P_3) and 150-µm low density polyethylene film (P_4). The control samples (P_1) were not packed but kept in plastic trays. These packaging materials were procured from M/s Arihant Plastics Pvt Ltd, Calcutta.

The inner portion and the lids of packages were first cleaned with teepol detergent solution and then they were chemically sterilized with 0.5% v/v hydrogen peroxide solution. This solution was kept in contact with the product surface side for 5 min and then these were air dried. The whole operation was carried ont in a packaging room as far as practicable under aseptic conditions.

Two hundred g of samples in each of 36 unit packages of each lot, 12 stored for each packaging material, were sealed and stored. The study was conducted within a temperature range of 6-32°C and relative humdity of 44-88%. The unit packages were withdrawn at an interval of every 30 days and subjected to sensory and physicochemical analyses. The expected shelf-life of the product under each packaging condition was also calculated from the regression line of the mean of total scores of sensory evaluation on storage period, assuming total score 15 to be the limit, below which the product was not acceptable.

3.2.9. Sorption studies

3.2.9.1. Establishing moisture sorption isotherms

The procedure suggested by Wolf *et al.* (1985) was followed. The sorption apparatus was used in equilibration studies. Wide-mouthed glass bottles (200 ml) with vapour-tight lids were used as sorbostats. Inside each sorbostat there was a support for weighing bottle, in which the sample material was exposed to the humid atmosphere in the container. For temperature control, the sorption containers were placed at 15, 25, 35 and 45°C.

Ten reagent grade salt slurries, namely lithium chloride, potassium acetate, magnesium chloride, magnesium nitrate, copper chloride, sodium chloride, ammonium sulphate, potassium chloride, potassium nitrate and potassium sulphate, chosen according to Greenspan (1977) in the a_w range of 0.113-0.979 acted as sorbate source, each glass bottle representing a specific relative humidity. The salts were dissolved in distilled water at 100°C and cooled to each test temperature of 15, 25, 35 and 45°C for crystallization to form a saturated slush. Freshly made dudh churpi under optimized condition was studied. Approximately 2 g of finely ground powder was placed into the tared weighing bottle which was placed on the glass bead support in the sorption container (inside sorbostat). These beakers were equilibrated for a day with surroundings within the sorbostats before the samples were taken into them. Approximately 5 mg of potassium sorbate was added to each sample to prevent mould growth. The bottles were tightly closed and placed in incubators at different temperatures till equilibration was attained. The samples were weighed periodically and the equilibrium was judged to have been attained when the difference between three consecutive samples was less than 1 mg/g solids. After equilibration, the moisture content in the samples was determined by either gravimetric or substraction method, and expressed as g water/g solids.

To establish moisture sorption isotherms, the equilibrium moisture contents were plotted against relative humidities or water activities (a_w). As the product was expected to absorb moisture at all a_w levels, the effect of hysteresis was neglected.

3.2.9.2. Mathematical analysis of the isotherm

In order to predict a_w value from the moisture content, fitting of different equations to the data - either in whole range of isotherm or part of it - was tried. Temperature dependence of isotherm parameters for selected equations was also studied. The following equations were fitted to the data (Chirife and Iglesias 1978):

1. Smith

$$M = - b \ln (1 - a_w) + a$$

2. Bradley

$$\ln (1/a_w) = a.b^M$$

3. Henderson

$$1 - a_w = e^{aM}$$

4. Iglesias and Chirife

$$\ln (M + \sqrt{M^2 + M_{0.50}}) = a + b\ a_w$$

5. Kuhn

$$M = a + b\ (1/\ln a_w)$$

6. Mizrahi

$$a_w = \frac{a + M}{b + M}$$

7. Oswin

$$M = a\left[\frac{a_w}{(1 - a_w)}\right]^b$$

8. Halsey

$$a_w = e^{(-a/M^b)}$$

9. GAB equation

$$\frac{M}{M_m} = \frac{C.k.a_w}{(1 - k.a_w)\ (1 - k.a_w + C.k.a_w)}$$

10. BET

$$\frac{a_w}{(1 - a_w)M} = \frac{1}{M_m C} + \frac{a_w\ (C - 1)}{M_m C}$$

11. Langmuir

$$\frac{M}{M_m} = \frac{C_L\, a_w}{1 + C_L\, a_w}$$

12. Cauries model

$$\frac{1}{M} = \left[\frac{1 - a_w}{a_w}\right]^{2C/M_m}$$

13. Modified Mizhari

$$M = \frac{a + a_w(C.a_w+b)}{a_w - 1}$$

where, M = equilibrium moisture content (g/100 g solids),

M_m = monolayer moisture content,

$M_{0.5}$ = equilibrium moisture content at a_w 0.5 and

a, b, c, k, C_L, C = isotherm constants.

The parameters of the equations were estimated by fitting the mathematical model to the experimental data. The comparison of the goodness of fit for each equation was evaluated in terms of percent root mean square (%RMS) value:

$$\% \text{ RMS} = \sqrt{\frac{1}{n}\sum_{1}^{n}\left[\frac{M_{exp} - M_{cal}}{M_{exp}}\right]^2} \times 100$$

where, M_{exp} = experimental value of moisture content,
M_{cal} = calculated value of moisture content and
n = number of observations (experimental value).

3.2.10. Consumer acceptance of dudh churpi

The samples of ready-to-eat dudh churpi, made under optimized conditions, and the best quality market samples (approx. 10 g of each sample) were served to 254 probable consumers. Their response was elicited using a consumer survey form (Table 5) and analysed.

3.2.11. Cost of production of dudh churpi

An endeavour was made to assess the cost production of dudh churpi manufactured from 100 l cow milk per day. The yeild of dudh churpi and the cost of surplus fat realized after standardization of milk were taken into consideration.

3.2.12. Statistical analysis

Data on composition, sensory attributes and subjective and objective textural parameters were analysed using two-way randomized block design (Snedecor and Cochran 1967). Interrelationship among chemical and instrumental parameters, sensory attributes and intrinsic parameters and subjective and objective textural parameters were carried out (Croxton *et al.* 1975; Kapsalis and Moskowitz 1979; Moskowitz 1981) in order to develop linear and

Table 5. Score card for consumer survey of dudh churpi

Please answer the following questions :

1. Age: Under 16________ 16 to 25__________ 25 to 50________ over 50_______
2. Sex: Male___________ Female___________
3. Occupation ______________________ 4. Monthly income______________________
5. How often do you eat this product:
   - Several times a week________________
   - Several times a month________________
   - Several times a year or never_________________
6. When do you eat this product:
   - With meal___________________
   - Between meals__________________
   - As and when you desire_______________
   - On specific occasion ____________________
   - (please specify)

<u>Testing procedure</u>

You will recieve two samples numbered `1' and `2'. Taste both the samples and indicate your preference in the approriate box.

Preference (Check only one of the following):

I prefer sample 1 over 2

- Extremely __________________
- Very much __________________
- Moderately __________________
- Slightly __________________

I prefer sample 2 over 1

- Extremely __________________
- Very much __________________
- Moderately __________________
- Slightly __________________

I have no preference__________________

Reasons for preference: I prefer sample __________ because

- It has better flovour ____________
- It has better texture ____________
- It has better colour ____________
- It has better appearance__________
- Overall sensory quality is better_________

Date

Signature:

Name:

log-linear multivariate relationships. Exponential relationships were described by the model

$$y = \exp - k_1 t^{k_2}$$

where, k_1 and k_2 are constants and were determined by least square regression of experimental data (Raghavarao 1983). Model suggested by Page (1949) was used to determine drying characteristics of dudh churpi. Factorial design was used to evaluate the interactions of different drying characteristics and data obtained from packaging experiment (Snedecor and Cochran 1967).

4. RESULTS

4.1. Survey on traditional methods of preparation of dudh churpi

Following the survey in Bhutan, Sikkim and Darjeeling, a detailed information was obtained on different traditional methods of prepaaration of dudh churpi (Fig. 4). In the villages of the extreme north of Bhutan, dudh churpi is prepared from yak milk. Dzno, a cross breed of male yak (*Bos mutus*) and indigenous cow, is the common source of milk in the villages of North Sikkim. In Darjeeling, cow milk is used. Traditionally, a bamboo churn, partly similar to mathani, is used in defattening milk. Now a days, most of the producers are using small mechanical cream separators.

4.2. Analysis of market samples of dudh churpi

4.2.1. Chemical analysis

The proximate composition of dudh churpi is given in Table 6. The contents of mean moisture, fat, total protein, lactose, total sugar, ash, titratable acid, pH and energy value of the samples of Darjeeling differed significantly ($P<0.05$) from those of Bhutan and Sikkim. However, in respect of these parameters,the samples of Bhutan and Sikkim did not differ significantly ($P<0.05$). Water-dispersible protein of the samples of all the three sources varied significantly ($P<0.05$). Glucose-galactose content of the samples of Bhutan was significantly ($P<0.05$) lower than the samples of Sikkim and Darjeeling. While the coefficients of variation for fat, protein and total sugar contents of individual samples were as high as 33, 26 and 22% respectively, the coefficients were 11% for moisture, 10% for lactose and 13% for ash content. Being higher in fat content, the samples of Darjeeling had

Bhutan and Sikkim

Yak (Bhutan)/dzno (Sikkim) milk

↓

Defatted with bamboo churn

↓

Warmed

↓

Coagulated with previous batch of whey

↓

Whey filtered off

↓

Coagulum cooked in open pan till disappearance of free moisture

↓

Hot cooked curd wrapped in hessian cloth and pressed heavily in a wooden box over night

↓

Cut into pieces, made a ring with a cotton thread and dried over wooden fire for 5-7 days

↓

Partially dried product cooked in concentrated milk with a little amount of sugar

↓

Dried over wooden fire for 25-30 days

↓

Dudh churpi

Darjeeling

Cow/dzno milk

↓

Defatted with bamboo churn

↓

Warmed

↓

Coagulated with previous batch of whey

↓

Whey filtered off

↓

Coagulum pressed heavily for 2-3 h, cut into pieces, wrapped in hessian cloth and stitched

↓

Cut into pieces, made a ring with a cotton thread and dried over wooden fire for 1-2 days

↓

Dipped in hot milk with a little amount of sugar

↓

Dried for 25-30 days

↓

Dudh churpi

Fig. 4. Traditional methods of preparation of dudh churpi

Table 6. Proximate composition of market samples of dudh churpi from three different sources

Constituents	Sources		
	Bhutan	Sikkim	Darjeeling
Moisture (%)	15.39^{b} (10.82 -18.33)	15.91^{b} (12.86 - 19.82)	18.50^{a} (12.61 - 26.21)
Total fat (%)	9.94^{b} (8.13 - 13.01)	10.01^{b} (6.13 - 12.63)	14.00^{a} (9.63 - 18.93)
Free fat (%)	2.31^{b} (1.71 - 2.69)	2.50^{b} (1.80 - 3.08)	3.50^{a} (2.15 - 3.98)
Total protein (%)	62.35^{a} (58.93 - 66.47)	61.95^{a} (58.50 - 67.06)	58.63^{b} (50.56 - 68.67)
Water- dispersible protein (%)	4.13^{c} (2.12 - 6.32)	4.90^{b} (3.17 - 6.17)	7.90^{a} (6.85 - 8.33)
Lactose (%)	3.59^{a} (2.13 - 4.65)	3.51^{a} (2.11 - 4.81)	1.25^{b} (0.61 - 4.81)
Glucose-galactose (%)	0.93^{b} (0.55 - 1.24)	1.01^{a} (0.74 - 1.39)	1.11^{a} (0.67 - 1.52)
Total sugar (%)	5.23^{a} (3.34 - 6.22)	5.17^{a} (3.44 - 6.45)	2.82^{b} (1.82 - 4.14)
Ash (%)	7.14^{a} (5.38 - 9.11)	7.01^{a} (5.13 - 9.15)	6.11^{b} (3.98 - 8.73)
Titratable acidity (as % lactic acid)	0.31^{b} (0.21 - 0.44)	0.36^{b} (0.24 - 0.52)	1.75^{a} (1.31 - 2.52)
pH	5.43^{a} (4.67 - 5.98)	5.70^{a} (4.52 - 6.22)	4.65^{b} (3.62 - 6.11)
Energy (MJ/100 g)	1.55^{b} (1.38 - 1.75)	1.54^{b} (1.30 - 1.75)	1.60^{a} (1.27 - 1.99)

Data represent the means of 20 samples. Ranges are given in parentheses. Means with different superscripts in each row differ significantly ($P < 0.05$).

significantly ($P<0.05$) higher energy value than those of Bhutan and Sikkim.

Table 7 shows the intrinsic properties of market dudh chupri. The contents of lactic acid, free fatty acid (FFA), 2-thiobarbituric acid (TBA), tyrosine and percent reflectance of the samples of Darjeeling were significantly ($P<0.05$) higher than the samples of two other sources. On the other hand, 5-hydroxymethylfurfural (HMF) and p-dimethylaminobenzaldehyde (p-DMAB) reactivity of the samples of Darjeeling were significantly ($P<0.05$) lower than those of Bhutan and Sikkim. Wheras the contents of lactic acid, FFA, HMF and p-DMAB reactivity of the samples of Sikkim were significantly ($P<0.05$) higher than the samples of Bhutan, percent reflectance of the sample of Sikkim was significantly ($P<0.05$) lower than those of Bhutan.

4.2.2. Sensory analysis

The sensory scores of market samples of dudh churpi are presented in Table 8. The scores of the samples from Bhutan were significatly ($P<0.05$) higher compared to those from other two sources with respect to every sensory attribute. Samples of Darjeeling were criticized by the judges as rancid and brittle. Dudh churpi with high elasticity, firmness, smoothness, gumminess and chewiness, but low crumbliness was rated most desirable, with respect to overall textural quality (Table 9). The samples of Darjeeling had significantly ($P<0.05$) lower scores, with respect to all the textural attributes except crumbliness, than the samples of other two sources. Samples of Bhutan and Sikkim also exhibited significant ($P<0.05$) difference with respect to all the sensory textural attributes.

Table 7. Intrinsic properties of market samples of dudh churpi from three different sources

Parameters	Sources		
	Bhutan	Sikkim	Darjeeling
Lactic acid (%)	0.07^{c} (0.05 - 0.09)	0.09^{b} (0.06 - 0.12)	0.19^{a} (0.12 - 0.25)
Free fatty acid (as % Oleic acid)	0.93^{c} (0.62 - 1.23)	1.22^{b} (0.67 - 2.09)	1.86^{a} (1.11 - 2.46)
2-Thiobarbituric acid value (A_{530})	0.08^{b} (0.06 - 0.13)	0.08^{b} (0.06 - 0.10)	0.11^{a} (0.08 - 0.14)
Tyrosine (mg/g)	0.15^{b} (0.09 - 0.24)	0.16^{b} (0.09 - 0.25)	0.26^{a} (0.15 - 0.28)
Free HMF (μmol/g)	27.88^{b} (20.17 - 34.21)	30.39^{a} (23.56 - 37.94)	10.20^{c} (7.17 - 14.13)
Total HMF (μmol/g)	59.26^{b} (48.19 - 71.17)	62.04^{a} (48.32 - 71.32)	40.15^{c} (30.29 - 50.28)
p-DMAB reactvity (A_{545})	0.20^{b} (0.13 - 0.28)	0.23^{a} (0.15 - 0.32)	0.11^{c} (0.08 - 0.16)
Reflectance (%)	30.75^{b} (26.00 - 35.00)	28.40^{c} (23.00 - 34.00)	41.45^{a} (35.00 -47.00)

Data represent the means of 20 samples. Ranges are given in parentheses. Means with different superscripts in each row differ significantly ($P < 0.05$).

Table 8. Sensory scores of market samples of dudh churpi from three different sources

Attributes	Sources		
	Bhutan	Sikkim	Darjeeling
Flavour	8.35^{a} (6.28 - 9.28)	7.77^{b} (5.86 - 8.86)	5.09^{c} (3.43 - 6.86)
Body and texture	7.62^{a} (6.00 - 8.71)	6.75^{b} (4.00 - 7.86)	4.73^{c} (3.28 - 5.71)
Colour and appearence	4.26^{a} (3.71 - 4.71)	3.61^{b} (2.57 - 4.00)	2.01^{c} (1.29 - 2.43)
Total score	20.23^{a} (17.14 - 22.00)	18.13^{b} (12.71 - 20.00)	11.83^{c} (8.99 - 14.41)

Data represent the means of 20 samples. Ranges are given in parentheses. Means with different superscripts in each row differ significantly ($P < 0.05$).

Table 9. Sensory textural characteristics of market samples of dudh churpi from three different sources

Attributes	Sources		
	Bhutan	Sikkim	Darjeeling
Elasticity	8.10^{a} (6.43 - 9.71)	7.33^{b} (6.28 - 9.00)	7.26^{b} (6.43 - 8.14)
Firmness	8.13^{a} (6.71 - 9.71)	7.60^{b} (6.86 - 9.00)	5.88^{c} (5.00 - 7.00)
Crumbliness	1.36^{c} (0.71 - 2.00)	2.03^{b} (1.28 - 2.43)	4.32^{a} (3.00 - 5.14)
Smoothness	8.11^{a} (6.57 - 9.57)	7.24^{b} (6.42 - 8.85)	5.13^{c} (4.57 - 6.43)
Gumminess	8.28^{a} (7.14 - 9.42)	7.50^{b} (6.57 - 9.00)	5.08^{c} (4.28 - 6.28)
Chewiness	7.62^{a} (6.57 - 8.71)	6.06^{b} (5.00 - 7.42)	5.09^{c} (4.28 - 6.14)
Overall textural quality	8.02^{a} (6.85 - 9.00)	7.46^{b} (6.43 - 9.00)	5.06^{c} (4.00 - 6.00)

Data represent the means of 20 samples. Ranges are given in parentheses. Means with different superscripts in each row differ significantly ($P < 0.05$).

4.2.3. Instrumental analysis

The instrumental textural properties of market samples of dudh churpi are shown in Table 10. Samples of Darjeeling had significantly ($P<0.05$) lower values for all the Instron parameters compared to the samples of two other sources. Significant ($P<0.05$) differences among the samples of Bhutan and Sikkim for all the Instron parameters indicated the extent of textural variability of the market product.

4.2.4. Relationship between sensory attributes and intrinsic parameters

The coefficients of correlations between various sensory attributes and intrinsic parameters of market samples of dudh churpi presented in Table 11 indicate that flavour was negatively correlated ($P<0.001$) with lactic acid, FFA, TBA and tyrosine content (log-log model). Whereas lactic acid alone accounted for 54% variation in flavour, FFA, TBA, and tyrosine content showed much lower effect (Table 12: equations 1,2,3,4). The combined effects of lactic acid and FFA and lactic acid and tyrosine were mostly the same (Table 12: equations 7,8).Flavour scores positively correlated ($P<0.001$) with free HMF, total HMF and p-DMAB reactivity (Table 11). While free HMF alone could explain 61% variation in flavour, total HMF explained much less (Table 12: equations 5,6). The five variables namely lactic acid, FFA, TBA, tyrosine and total HMF jointly explained 62% variability in flavour, indicating that these parameters have no joint effect on flavour.

Body and texture scores of dudh churpi tended to decline with increasing lactic acid, FFA, TBA and tyrosine content, but showed a significant ($P<0.001$) positive correlation with free HMF, total HMF and p-

Table 10. Instrumental textural properties of market samples of dudh churpi from three different sources

Attributes	Sources		
	Bhutan	Sikkim	Darjeeling
Hardness(N)	363.50[a] (238.00 - 507.00)	207.65[b] (142.00 - 296.00)	163.30[c] (118.00 - 214.00)
Cohesiveness	0.52[a] (0.35 - 0.78)	0.41[b] (0.38 - 0.58)	0.30[c] (0.23 - 0.46)
Springiness (mm)	1.05[a] (0.70 - 1.85)	0.93[b] (0.70 - 1.10)	0.73[c] (0.55 - 0.85)
Gumminess (N)	179.46[a] (78.20 - 365.40)	105.70[b] (60.68 - 168.72)	84.99[b] (42.35 - 145.52)
Chewiness (N.mm)	130.24[a] (62.56 - 310.59)	104.48[b] (69.52 - 145.90)	78.35[c] (33.88 - 138.24)

Data represent the means of 20 samples. Ranges are given in parentheses. Means with different superscripts in each row differ significantly ($P < 0.05$).

Table 11. Coefficients of correlations between sensory scores and intrinsic parameters of market samples of dudh churpi

	Sensory attributes			
Intrinsic parameters	Flavour	Body and texture	Colour and appearance	Total score
Lactic acid	-0.731 (-0.713)	-0.663 (-0.648)	-0.837 (-0.832)	-0.772 (-0.759)
Total HMF	0.678 (0.655)	0.607 (0.595)	0.725 (0.741)	0.700 (0.692)
Free HMF	0.766 (0.780)	0.711 (0.734)	0.815 (0.857)	0.799 (0.828)
Free fatty acid	-0.618 (-0.602)	-0.559 (-0.547)	-0.740 (-0.731)	-0.660 (-0.651)
2-Thiobarbituric acid value	-0.494 (-0.475)	-0.433 (-0.425)	-0.589 (-0.568)	-0.521 (-0.509)
Tyrosine	-0.536 (-0.507)	-0.469 (-0.447)	-0.618 (-0.578)	-0.560 (-0.535)
p-DMAB reactivity	0.583 (0.651)	0.493 (0.561)	0.638 (0.733)	0.594 (0.675)

Figures in parentheses are coefficients of correlations for log-linear relationships. Values are significant at $P<0.001$ (58 d.f.).

Table 12. Regression equations for sensory scores as related to intrinsic parameters of market samples of dudh churpi

Equations*	Coefficient of correlation (R)**
1. $FI = 9.59 - 21.73LA$	0.73
2. $FI = 9.79 - 2.04FFA$	0.62
3. $FI = 10.31 - 3.49TBA$	0.49
4. $FI = 10.17 - 17.54Ty$	0.54
5. $FI = 0.74FHMF^{0.39}$	0.78
6. $FI = 1.74 + 0.10THMF$	0.68
7. $FI = 10.15 - 16.90LA - 0.84FFA$	0.76
8. $FI = 10.47 - 18.40LA - 7.13Ty$	0.76
9. $FI = 7.75 - 13.06LA + 0.04THMF - 6.35Ty$	0.77
10. $FI = 7.80 - 10.88LA - 0.64FFA + 3.17TBA - 4.90Ty + 0.04THMF$	0.78
11. $BT = 8.46 - 18.01LA$	0.66
12. $BT = 8.61 - 1.68FFA$	0.56
13. $BT = 8.97 - 28.47TBA$	0.43***
14. $BT = 8.84 - 14.01Ty$	0.47
15. $BT = 2.00 + 0.08THMF$	0.61
16. $BT = 0.73FHMF^{0.36}$	0.73
17. $BT = 8.91 - 14.06LA - 0.68FFA$	0.69
18. $BT = 9.09 - 15.59LA - 5.19Ty$	0.68

Table 12. Continued

Equations*	Coefficient of correlation (R)**
19. $BT=6.17-13.04LA+0.03THMF$	0.68
20. $BT=0.35THMF^{0.46}.pDMAB^{0.19}$	0.63
21. $BT=6.98-11.45LA+0.03THMF-4.59Ty$	0.69
22. $BT=0.34THMF^{0.45}.pDMAB^{0.19}.TBA^{-0.01}$	0.63
23. $BT=6.84-9.78LA-0.55FFA+4.22TBA-3.30Ty+0.30THMF$	0.71
24. $CA=5.02-14.90LA$	0.84
25. $CA=5.24-1.46FFA$	0.74
26. $CA=-0.73TBA^{-0.77}$	0.57
27. $CA=-0.52FHMF^{0.55}$	0.86
28. $CA=-3.28THMF^{1.11}$	0.74
29. $CA=2.30pDMAB^{0.65}$	0.73
30. $CA=5.47-10.96LA-0.68FFA$	0.88
31. $CA=-1.47LA^{-0.48}.THMF^{0.38}$	0.85
32. $CA=-3.19TBA^{-0.21}.THMF^{0.96}$	0.75
33. $CA=4.61-10.55LA+0.01THMF-4.71Ty$	0.87
34. $CA=5.17-8.07LA-0.55FFA-1.41TBA-3.55Ty+0.01THMF$	0.90
35. $CA=0.39LA^{-0.32}.FFA^{-0.22}.TBA^{-0.02}.Ty^{-0.19}.pDMAB^{0.19}$	0.90
36. $CA=-0.16LA^{-0.29}.FFA^{-0.21}.TBA^{0.01}.Ty^{-0.18}.THMF^{0.18}.pDMAB^{0.17}$	0.90

Table 12. Continued

Equations*	Coefficient of correlation (R)**
37. $TSc = 1.79LA^{-0.44}$	0.76
38. $TSc = 1.56FHMF^{0.41}$	0.81
39. $TSc = 3.62+0.24THMF$	0.70
40. $TSc = 3.60pDMAB^{0.46}$	0.68
41. $TSc = 24.53-41.92LA-2.20FFA$	0.80
42. $TSc = 16.55-40.48LA+0.09THMF$	0.79
43. $TSc = 19.34-35.06LA+0.08THMF-15.64Ty$	0.81
44. $TSc = 19.80-28.72LA-1.74FFA+5.98TBA-11.76TY+.0.08THMF$	0.82

*Fl, flavour

LA, lactic acid

FFA, free fatty acid

TBA, 2-thiobarbituric acid

Ty, tyrosine

FHMF, free hydroxymethylfurfural

THMF, total hydroxymethylfurfural

BT, body and texture

pDMAB, p-dimethylaminobenzaldehyde reactivity

CA, colour and appearance

TSc, total score

** Significant at $P<0.001$

*** Significant at $P<0.01$

DMAB reactivity (Table 11). Whereas lactic acid explained 44% variation in body and texture, free HMF showed a much greater effect (Table 12: equations 11,16). The combined effect of lactic acid, FFA, TBA, tyrosine and total HMF did not predict better than that predicted by free HMF alone (Table 12: equation 23).

The colour and appearance scores of dudh churpi were greatly dependent upon all the intrinsic parameters (Table 11). Relevant regression equations showed that free HMF alone could account for 74% colour and appearance scores and lactic acid alone for 70% (Table 12: equations 27,24). Whereas lactic acid and FFA jointly explained 77% variation in colour and appearance, the combined effect of total HMF and tyrosine explained 76% variation (Table 12: equations 30,33). All the intrinsic parameters taken together explained 81% variability in colour and appearance scores of market samples of dudh churpi (Table 12: equation 36).

The total score of dudh churpi was negatively influenced by lactic acid, FFA, TBA and tyrosine content of dudh churpi (Table 11). Free HMF, total HMF and p-DMAB reactivity bore a positive correlation ($P<0.001$) with total scores of market samples of dudh churpi (Table 11). Whereas lactic acid alone accounted for 58% variation in total scores, free HMF showed a slightly greater effect (Table 12: equation 37,38). All the intrinsic parameters jointly explained 68% variation in total scores of market samples of dudh churpi.

4.2.5. Relationship between chemical composition and Instron parameters

Table 13 shows the coefficients of correlations between various texture profile parameters and compositional characteristics of dudh churpi. Instron hardness was positively correlated ($P<0.01$) with total solids. Water-dispersible

Table 13. Coefficients of correlations between proximate composition and Instron parameters of market samples of dudh churpi (58 d.f.)

Compositional variables	Hardness	Instron parameters			
		Cohesiveness	Springiness	Gumminess	Chewiness
Total solids	0.339**	0.010	-0.194	0.321*	0.264*
	(0.383)**	(-0.035)	(-0.234)	(0.331)**	(0.260)*
Total fat	-0.372**	-0.056	-0.015	-0.342**	-0.356**
	(-0.381)**	(-0.072)	(0.004)	(-0.385)**	(-0.427)**
Free fat	-0.539**	-0.038	0.189	-0.498**	-0.451**
	(-0.578)**	(-0.068)	(0.280)*	(-0.562)**	(-0.506)**
Total protein	0.319*	0.002	-0.034	0.275*	0.265
	(0.364)**	(0.018)	(-0.086)	(0.323)*	(0.313)*
Water-dispersible protein	-0.589**	-0.003	-0.248	-0.487**	-0.397**
	(-0.635)**	(-0.022)	(0.355)**	(-0.590)**	(-0.491)**
Total sugar	0.479**	-0.098	0.092	0.392**	0.364**
	(0.577)**	(-0.097)	(0.015)	(0.475)**	(0.459)**
Titratable acidity	-0.544**	0.146	0.110	-0.414**	-0.393**
	(-0.637)**	(0.119)	(0.190)	(-0.518)**	(-0.492)**

Figures in parentheses are coefficients of correlations for log-linear relationships.

*Significant at $P<0.05$

**Significant at $P<0.01$

protein (WDP) showed a greater but equally significant negative correlation with hardness. The log linear relationship exhibited greater correlations as compared to linear ralationships for all chemical parameters affecting hardness. Whereas total solids alone accounted for 15% variation in hardness, WDP showed a much greater effect (40%) (Table 14: equations 1,3). The combined effect of total solids and WDP was near the combined effects of total sugar and WDP, and total sugar, WDP and free fat (Table 14: equations 7,9,11). These regressions provided slightly better prediction of hardness than that based on WDP alone.

Cohesiveness tended to decline with increasing total solids and so with increasing total fat, free fat, WDP and toal sugar contents (Table 13). The positive correlation of cohesiveness with total protein and titratable acidity were much smaller and non-significant. Regression analysis indicated that all the compositional parameters taken together explained only 23% variation in cohesiveness (Table 14: equation 16).

Springiness did not seem to be influenced by the compositional variables studied, although its correlation with WDP appeared to be appreciable (Table 13).

Gumminess was greatly dependent upon fat, WDP, total sugar and titratable acidity (Table 13). The coefficients of correlation are higher for the log-log model. Relevant regression equations showed that WDP alone could account for 35% gumminess, whereas titratable acidity accounted for 27% gumminess (Table 14: equations 24,25). The combined effect of total sugar, titratable acidity, free fat and WDP was higher (Table 14: equation 27).

Chewiness showed less dependence on the compositional parameters than gumminess. Combination of total solids, total fat, total protein, total sugar, free fat and WDP predicted better chewiness than any other single parameter (Table 14: equations 35, 30-32).

Table 14. Regression equations for Instron texture parameters as related to composition of market samples of dudh churp

Equations*	Coefficient of Correlation (R)**
1. $H = -12.90TS^{4.14}$	0.38
2. $H = -4.60P^{2.44}$	0.36
3. $H = 6.67WDP^{-0.74}$	0.64***
4. $H = 6.93F^{-0.63}$	0.38
5. $H = 6.38FF^{-0.97}$	0.58***
6. $H = 4.50TSu^{0.64}$	0.58***
7. $H = -1.12TS^{1.73}.WDP^{-0.67}$	0.65***
8. $H = -0.04TS^{1.15}.TSu^{0.59}$	0.58***
9. $H = 5.85TSu^{0.32}.WDP^{-0.53}$	0.67***
10. $H = 5.81TSu^{0.17}.WDP^{-0.41}.TA^{-0.11}$	0.68***
11. $H = 6.09TSu^{-0.19}.FF^{-0.27}.WDP^{-0.45}$	0.68***
12. $H = 1.66TS^{1.02}.TA^{-0.12}.FF^{-0.21}.WDP^{-0.36}$	0.69***
13. $H = 3.76TS^{-2.25}.F^{0.57}.P^{2.53}.TSu^{0.29}.TA^{-0.15}.WDP^{-0.38}$	0.70***
14. $C = 0.54+0.01P+0.12TA-0.06FF-0.02WDP$	0.36
15. $C = 0.78-0.01F+0.13TA-0.06FF-0.02WDP$	0.39
16. $C = 0.23+0.03TS-0.04F-0.03P-0.04TSu+0.12TA-0.02WDP$	0.48***
17. $Spr = 0.38FF^{0.26}$	0.28

Table 14. Continued

Equations*	Coefficient of correlation (R)**
18. $Spr = 0.51WDP^{0.23}$	0.36
19. $Spr = 5.03TS^{-2.97}.F^{0.07}.P^{1.63}.TSu^{0.03}.FF^{0.20}.WDP^{0.30}$	0.49***
20. $Spr = 5.47TS^{-2.94}.F^{0.07}.P^{1.53}.TSu^{0.26}.TA^{0.02}.WDP^{0.34}$	0.46
21. $G = -12.65TS^{3.93}$	0.33
22. $G = -5.02P^{2.37}$	0.32
23. $G = 3.89TSu^{0.[illegible]8}$	0.48***
24. $G = 5.99WDP^{-0.76}$	0.59***
25. $G = 4.56TA^{-0.27}$	0.52***
26. $G = 2.35TS^{0.83}.FF^{-0.50}.WDP^{-0.48}$	0.63***
27. $G = 5.98TSu^{0.10}.TA^{0.04}.FF^{-0.53}.WDP^{-0.51}$	0.63***
28. $G = 4.44P^{0.4[illegible]}TA^{0.02}.FF^{-0.54}.WDP^{-0.50}$	0.63
29. $G = 0.55TS^{2.59}.F^{-0.44}.P^{-1.19}.TSu^{0.08}.TA^{0.05}.WDP^{-0.61}$	0.61***
30. $Ch = -3.29P^{1.92}$	0.31
31. $Ch = 3.91TSu^{[illegible].47}$	0.46***
32. $Ch = 5.46WDP^{-0.52}$	0.49***
33. $Ch = 5.17TSu^{0.14}.FF^{-0.39}.WDP^{-0.24}$	0.55***
34. $Ch = 5.31FF^{-0.40}.WDP^{-0.22}.TA^{-0.06}$	0.55***
35. $Ch = 5.16TS^{0.62}.F^{-0.35}.P^{-0.47}.TSu^{0.08}.FF^{-0.33}.WDP^{-0.18}$	0.57***

Table 14. Continued

Equations*	Coefficient of correlation (R)**
36. $Ch = 4.62TS^{0.60}.F^{-0.42}.P^{-0.36}.TSu^{0.22}.TA^{0.04}.WDP^{-0.30}$	0.55***

*H, hardness
TS, total solids
P, total protein
WDP, water-dispersible protein
F, total fat
FF, free fat
TSu, total sugar
TA, titratable acidity
C, cohesiveness
Spr, springiness
G, gumminess
Ch, chewiness

** Significant at P<0.01

*** Significant at P<0.001

A negative correlation was observed between hardness and cohesiveness (Table 15). But gumminess and chewiness bore the opposite relationships with hardness ($P<0.001$). Cohesiveness exhibited negative correlation with springiness but significant ($P<0.001$) positive correlation with gumminess and chewiness. Chewiness showed a significant positive correlation ($P<0.001$) with gumminess but a less significant ($P<0.01$) negative correlation with springiness exhibiting a more chewy and less springy dudh churpi.

4.2.6. Relationship between sensory textural descriptors and Instron texture profile

Correlations between sensory texture descriptors and instrumental texture parameters of dudh churpi are given in Table 16. The sensory firmness was highly correlated ($P<0.001$) with Instron hardness. The log-linear relationship was appreciably higher than the linear one. Instron hardness reflected 42% sensory firmness (Table 17: equation 1). Instron hardness also showed significant ($P<0.001$) positive correlation with sensory elasticity, smoothness, gumminess, chewiness and overall textural quality, and negative correlation ($P<0.001$) with crumbliness (Table 16). The correlation being higher for log-log model in all the cases excepting sensory elasticity. Thus, hardness could account for 56% crumbliness, 26% elasticity, 48% smoothness, 49% sensory gumminess, 55% sensory chewiness and 43% overall textural quality (Table 17: equations 9,17,22,25,30,39).

Cohesiveness measured by Instron was not significantly correlated with any of the sensory textural descriptors (Table 16).

Instrumental springiness bore no significant correlation with firmness, smoothness, sensory gumminess and overall textural quality (Table 16). However, this was positively correlated ($P<0.01$) with crumbliness and

Table 15. Coefficients of correlations among different Instron texture parameters of market samples of dudh churpi (58 d.f.)

Parameters	Hardness	Cohesiveness	Springiness	Gumminess	Chewiness
Hardness	1.000 (1.000)				
Cohesiveness	-0.072 (-0.107)	1.000 (1.000)			
Springiness	-0.465* (-0.530)*	-0.102 (-0.077)	1.000 (1.000)		
Gumminess	0.960* (0.855)*	0.455* (0.424)*	-0.451* (-0.571)*	1.000 (1.000)	
Chewiness	0.849* (0.724)*	0.469* (0.466)*	-0.123 (-0.315)**	0.904* (0.906)*	1.000 (1.000)

Figures in parentheses are coefficients of correlations for log-linear relationships.

*Significant at P<0.001

**Significant at P<0.01

Table 16. Coefficients of correlations between sensory texture descriptors and Instron texture parameters of market samples of dudh churpi (58 d.f.)

Instron parameters	Sensory texture descriptors						
	Firmness	Crumbliness	Elasticity	Smoothness	Gumminess	Chewiness	Overall textural quality
Hardness	0.612* (0.652)*	-0.637* (-0.745)*	0.513* (0.495)*	0.666* (0.696)*	0.660* (0.703)*	0.715* (0.745)*	0.574* (0.656)*
Cohesiveness	-0.051 (-0.068)	0.001 (-0.007)	0.003 (-0.023)	-0.056 (-0.081)	-0.064 (-0.083)	-0.099 (-0.127)	-0.045 (-0.065)
Springiness	-0.164 (-0.170)	0.258** (0.403)*	-0.317** (-0.308)**	-0.219 (-0.237)	-0.192 (-0.223)	-0.305** (-0.361)*	-0.143 (-0.190)
Gumminess	0.511* (0.558)*	-0.553* (-0.682)*	0.449* (0.439)*	0.548* (0.592)*	0.536* (0.597)*	0.570* (0.613)*	0.471* (0.663)*
Chewiness	0.529* (0.565)*	-0.482* (-0.567)*	0.427* (0.372)*	0.522* (0.560)*	0.517* (0.566)*	0.449* (0.501)*	0.436* (0.541)*

Figures in parentheses are coefficients of correlations for log-linear relationships.

*Significant at $P<0.01$
**Significant at $P<0.05$

Table 17. Regression equations between sensory texure descriptors and Instron texture profile of market samples of dudh churpi

Equations*	Coefficient of correlation (R)**
1. $Fr = 0.42H^{0.28}$	0.65
2. $Fr = 0.91G^{0.27}$	0.56
3. $Fr = 0.42H^{0.28}.C^{0.01}$	0.65
4. $Fr = 0.15H^{0.34}.Spr^{0.18}$	0.68
5. $Fr = 0.06C^{-0.32}.Ch^{0.36}$	0.68
6. $Fr = 0.16H^{0.17}.C^{0.17}.Spr^{0.03}.G^{0.18}$	0.68
7. $Fr = 0.16H^{0.19}.C^{0.15}.Spr^{0.03}.Ch^{0.18}$	0.68
8. $Fr = 0.14H^{-12.05}.C^{1.18}.Spr^{-13.55}.G^{0.18}.Ch^{13.57}$	0.68
9. $Cr = 6.25H^{-1.0}$	0.75
10. $Cr = 0.93Spr^{0.9}$	0.40***
11. $Cr = 4.76G^{-0.84}$	0.68
12. $Cr = 6.17H^{-1.02}.C^{-0.21}$	0.75
13. $Cr = 0.98C^{0.06}.Spr^{0.99}$	0.40***
14. $Cr = 6.02H^{-1.18}.C^{-104.37}.G^{-104.34}.Ch^{104.52}$	0.77
15. $Cr = 6.28H^{-0.85}.Spr^{0.27}.G^{-0.10}.Ch^{-0.20}$	0.76
16. $Cr = 6.14^{-94.58}.C^{-10.31}.Spr^{-104.10}.G^{-0.09}.Ch^{103.88}$	0.77
17. $El = 6.60 + 0.01H$	0.51
18. $El = 8.57 - 1.22Spr$	0.32***

Table 17. Continued

Equations*	Coefficient of correlation (R)**
19. $El = 7.07 + 0.01H - 0.42Spr$	0.52
20. $El = 8.82 - 0.01H - 2.36C - 1.23Spr + 0.01Ch$	0.56
21. $El = 8.49 + 0.001H - 1.28C - 1.55Spr - 0.01G + 0.02Ch$	0.57
22. $Sm = -0.18H^{0.38}$	0.70
23. $Sm = -0.43H^{0.43}.Spr^{0.17}$	0.71
24. $Sm = -0.47H^{-34.54}.C^{-3.68}.Spr^{-38.60}.G^{0.18}.Ch^{38.66}$	0.72
25. $SG = -0.33H^{0.41}$	0.70
26. $SG = -0.62H^{0.47}.Spr^{0.21}$	0.72
27. $SG = 0.40G^{0.32}$	0.60
28. $SG = -0.37H^{0.53}.C^{-35.11}.G^{-35.22}.Ch^{35.21}$	0.71
29. $SG = -0.69H^{-32.86}.C^{-3.46}.Spr^{-36.80}.G^{0.23}.Ch^{36.81}$	0.73
30. $SCh = -0.19H^{0.37}$	0.74
31. $SCh = 0.51G^{0.28}$	0.61
32. $SCh = 0.57Ch^{0.27}$	0.50
33. $SCh = -0.20H^{0.37}.C^{-0.04}$	0.75
34. $SCh = -0.20H^{0.41}.G^{-0.04}$	0.75
35. $SCh = -0.15H^{0.39}.Ch^{-0.04}$	0.75
36. $SCh = 0.65G^{0.37}.Ch^{-0.13}$	0.62

Table 17. Continued

Equations*	Coefficient of correlation (R)**
37. $SCh = -0.23H^{0.34}.C^{-24.16}.G^{-24.23}.Ch^{24.18}$	0.75
38. $SCh = -0.27H^{-21.63}.C^{-2.40}.Spr^{-24.45}.G^{0.03}.Ch^{24.41}$	0.75
39. $OTQ = -0.11H^{0.37}$	0.66
40. $OTQ = 0.53G^{0.29}$	0.56
41. $OTQ = 0.36Ch^{0.33}$	0.54
42. $OTQ = -0.42H^{0.43}.Spr^{0.21}$	0.68
43. $OTQ = -0.11H^{0.37}.C^{0.01}$	0.66
44. $OTQ = 0.41G^{0.20}.Ch^{0.11}$	0.57
45. $OTQ = -0.43H^{0.24}.C^{0.20}.Spr^{0.03}.G^{0.23}$	0.68
46. $OTQ = -0.47H^{-33.08}.C^{-3.47}.Spr^{-36.98}.G^{0.23}.Ch^{37.00}$	0.69

*Fr, firmness

H, hardness

G, gumminess (Instron)

C, cohesiveness

Spr, springiness

Ch, chewiness (Instron)

Cr, crumbliness

El, elasticity

Sm, smoothness

SG, sensory gumminess

SCh, sensory chewiness

OTQ, overall textural quality

** Significant at P<0.001

*** Significant at P<0.01

negatively correlated ($P<0.05$) with elasticity. Springiness alone predicted 16% crumbliness and only 10% elasticity (Table 17: equations 10,18). Coupled with hardness, springness explained 46% firmness, and in combination with hardness, cohesiveness, gumminess and chewiness explained 59% crumbliness, 52% smoothness, 53% sensory gumminess, 56% sensory chewiness and 47% overall textural quality (Table 17: equations 4,14,24,29,38,46).

Instron gumminess and Instron chewiness showed a positive correlation ($P<0.01$) with all the sensory texture descriptors except crumbliness (Table 16). The correlations were higher for log-log model, excepting with elasticity. Thus, gumminess explained 31% firmness, 47% crumbliness, 36% sensory gumminess, 38% sensory chewiness and 32% overall textural quality (Table 17: equations 2,11,27,31,40). Instrumental chewiness, when correlated with sensory chewiness, explained only 25% variability (Table 17: equation 32). Sensory chewiness was better predicted jointly either by hardness and cohesiveness, hardness and gumminess, hardness and chewiness. Combination of all the instrumental parameters did not improve the predictability of the sensory chewiness (Table 17: equations 33,34,35,38). Whereas Instron hardness coupled with cohesiveness explained 43% and with springness explained 46% overall sensory texture score (Table 17: equation 43,42), 47% of the same could be explained by all the Instron texture parameters taken together (Table 17: equation 46).

4.3. Optimization of process parameters in the manufacture of dudh churpi

4.3.1. Milk used for cooking prechurpi

4.3.1.1. Fat level

The influence of different fat levels in cow milk, used for cooking, on the sensory attributes of dudh churpi is shown in Table 18. Prechurpi when cooked in milk of 1% fat scored significantly ($P<0.05$) higher with respect to each sensory attribute than the samples cooked in milk of 2.0 and 3.0% fat. It had the desired body, smooth texture and characteristic flavour. Dudh churpi prepared by cow skim milk of 0.1% fat was criticized as having flat flavour. However, these samples did not differ significantly ($P<0.05$) with respect to body, texture, colour and appearance with the samples, cooked in milk of 1.0% fat. The samples of dudh churpi, cooked in milk of 2.0 and 3.0% fat, were criticized as having slight to pronounced rancid flavour and soft body.

Instrumental analysis of dudh churpi, cooked in milk of different fat levels showed that the mean values of almost all the instrumental parameters of dudh churpi cooked in skim milk of 0.1% fat were significantly ($P<0.05$) higher than the samples cooked in milk of other fat levels (Table 19). While hardness, cohesiveness, gumminess and chewiness varied almost inversely with increase in fat level of milk used for cooking, except springiness which showed an opposite effect.

The chemical composition of dudh churpi as influenced by different fat levels in milk, used for cooking, is presented in Table 20. The moisture content of dudh churpi varied almost inversely with fat level in milk. However, total fat, free fat, total protein, lactose, total sugar and ash increased with the increase in fat level.

Fat levels in milk used for cooking had no significant ($P<0.05$) relation with lactic acid, tyrosine and p-DMAB reactivity of dudh churpi (Table 21). While FFA and TBA values increased with the increase in fat level, free and total HMF values decreased correspondingly.

Table 18. Sensory attributes of dudh churpi as influenced by fat level in milk used for cooking

Attributes	Fat content (%)			
	0.1	1.0	2.0	3.0
Flavour	7.00[b] (6.71 - 7.28)	8.35[a] (8.28 - 8.43)	7.65[b] (7.43 - 7.71)	6.00[c] (5.86 - 6.14)
Body and texture	8.00[a] (7.86 - 8.14)	8.00[a] (7.86 - 8.14)	7.46[b] (7.28 - 7.71)	6.00[c] (5.86 - 6.14)
Colour and appearance	4.75[a] (4.71 - 4.86)	4.82[a] (4.71 - 4.86)	3.68[b] (3.57 - 3.86)	3.07[c] (2.86 - 3.28)
Total score	19.75[b] (19.28 - 20.28)	21.17[a] (21.14 - 21.28)	18.79[b] (18.28 - 19.28)	15.07[c] (14.86-15.56)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P < 0.05$).

Table 19. Instrumental texture profile of dudh churpi as influenced by fat level in milk used for cooking

Attributes	Fat (%)			
	0.1	1.0	2.0	3.0
Hardness (N)	405.25[a] (396.00-417.00)	361.75[b] (354.00-372.00)	345.25[b] (341.00-349.00)	326.00[c] (305.00-340.00)
Cohesiveness	0.63[a] (0.58-0.67)	0.59[ab] (0.57-0.62)	0.56[b] (0.53-0.58)	0.46[c] (0.44-0.48)
Springiness (mm)	0.66[c] (0.60-0.70)	0.71[bc] (0.65-0.75)	0.75[ab] (0.70-0.80)	0.81[a] (0.75-0.85)
Gumminess (N)	255.30[a] (231.42-274.03)	213.52[b] (204.63-230.64)	193.34[c] (182.85-202.42)	149.80[d] (146.40-156.04)
Chewiness (N.mm)	169.08[a] (152.62-191.82)	152.14[ab] (133.01-161.45)	145.25[b] (128.00-161.94)	121.75[c] (112.20-132.63)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly (P<0.05).

Table 20. Chemical parameters of dudh churpi as influenced by fat level in milk used for cooking

Parameters	Fat (%)			
	0.1	1.0	2.0	3.0
Moisture (%)	16.03^{a} (15.93 - 16.08)	15.41^{b} (15.36 - 15.46)	14.93^{c} (14.91 - 14.96)	13.88^{d} (13.86 - 13.90)
Total fat (%)	7.67^{d} (7.62 - 7.71)	7.80^{c} (7.78 - 7.82)	8.06^{b} (8.04 - 8.08)	8.39^{a} (8.37 - 8.41)
Free fat (%)	1.65^{d} (1.63 - 1.67)	2.12^{c} (2.08 - 2.16)	2.96^{b} (2.94 - 2.98)	3.05^{a} (3.02 - 3.08)
Total protein (%)	64.53^{c} (64.49 - 64.56)	64.96^{b} (64.90 - 65.02)	64.98^{b} (64.94 - 65.06)	65.56^{a} (65.47 - 65.61)
Water- dispersible protein (%)	4.15^{a} (4.12 - 4.18)	4.16^{a} (4.11 - 4.21)	4.17^{a} (4.15 - 4.19)	4.17^{a} (4.11 - 4.21)
Lactose (%)	3.14^{b} (3.10 - 3.18)	3.16^{b} (3.13 - 3.18)	3.17^{b} (3.13 - 3.21)	3.22^{a} (3.20 - 3.24)
Glucose-galactose (%)	0.76^{a} (0.72 - 0.79)	0.76^{a} (0.74 - 0.78)	0.77^{a} (0.75- 0.79)	0.78^{a} (0.76 - 0.80)
Total sugar (%)	4.92^{b} (4.88 - 4.98)	4.94^{b} (4.92 - 4.96)	5.10^{a} (5.08 - 5.12)	5.15^{a} (5.11 - 5.19)
Ash (%)	6.85^{c} (6.87 - 6.83)	6.90^{b} (6.88 - 6.92)	6.93^{b} (6.91 - 6.95)	7.02^{a} (7.01 - 7.03)
Titratatable acidity (as % lactic acid)	0.31^{a} (0.30 - 0.32)	0.31^{a} (0.29 - 0.33)	0.32^{a} (0.30 - 0.34)	0.33^{a} (0.31 - 0.35)
pH	5.45^{a} (5.41 - 5.47)	5.45^{a} (5.41 - 5.47)	5.42^{ab} (5.40 - 5.44)	5.39^{b} (5.36 - 5.42)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P < 0.05$).

Table 21. Intrinsic parameters of dudh churpi as influenced by fat level in milk used for cooking

Attributes	Fat (%)			
	0.1	1.0	2.0	3.0
Lactic acid (%)	0.04[a] (0.03-0.05)	0.04[a] (0.03-0.05)	0.05[a] (0.04-0.06)	0.05[a] (0.04-0.06)
Free fatty acid (as % oleic acid)	0.85[d] (0.83-0.87)	0.95[c] (0.93-0.97)	1.09[b] (1.03-1.15)	1.22[a] (1.20-1.24)
2-Thiobarbituric acid value (A_{530})	0.02[d] (0.02-0.03)	0.06[c] (0.05-0.07)	0.08[b] (0.07-0.09)	0.09[a] (0.09-0.10)
Tyrosine (mg/g)	0.16[a] (0.15-0.17)	0.16[a] (0.15-0.17)	0.15[a] (0.13-0.17)	0.14[a] (0.12-0.16)
Free HMF (µmol/g)	27.89[a] (27.83-27.95)	27.69[b] (27.65-27.73)	27.61[c] (27.59-27.63)	27.64[c] (27.61-27.66)
Total HMF (µmol/g)	59.26[a] (59.24-59.28)	59.11[b] (59.06-59.16)	59.03[c] (59.01-59.05)	58.93[d] (58.91-58.97)
p-DMAB reactivity (A_{545})	0.22[a] (0.20-0.24)	0.21[a] (0.19-0.23)	0.21[a] (0.20-0.22)	0.20[a] (0.18-0.22)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly (P<0.05).

4.3.1.2. Sugar concentration

Prechurpi was cooked in milk of 1.0% fat, but varying concentrations of sugar. The sensory scores of each attribute increased with the increase in sugar concentration upto 2.0%, but declined significantly ($P<0.05$) when the concentration of sugar increased to 3.0% (Table 22).

The mean values for all the instrumental parameters of dudh churpi, cooked in milk of 2.0% sugar, were higher compared to the products cooked in milk of 0, 1.0 and 3.0% sugar (Table 23).

Variation in the concentration of sugar had no influence on the intrinsic parameters of dudh churpi, excepting FFA and HMF (Table 24) which increased in sugar concentration.

4.3.1.3. Total solids content

Milk of 1.0% fat and 2.0% sugar was concentrated to different total solids content ranging from 11.70 to 29.25% and used for cooking prechurpi. All the sensery attributes increased almost significantly ($P<0.05$) with the increase in total solids content (Table 25).

The mean values for Instron parameters increased with the increase in total solids content of milk (Table 26). But, no significant ($P<0.05$) difference was observed among the products when the total solids contents of milk were 23.4% and 29.25%.

4.3.2. Duration of prechurpi cooking time

Prechurpi was cooked in milk of 1.0% fat, 2.0% sugar and 29.25% total

Table 22. Sensory atributes of dudh churpi as influenced by sugar level in milk used for cooking

Attributes	Sugar (%)			
	0	1.0	2.0	3.0
Flavour	7.18[d] (7.00-7.28)	7.90[b] (7.86-8.00)	8.36[a] (8.28-8.43)	7.61[c] (7.57-7.71)
Body and texture	6.96[d] (6.86-7.14)	7.74[b] (7.71-7.86)	8.00[a] (7.86-8.14)	7.50[c] (7.73-7.57)
Colour and appearance	3.35[d] (3.38-3.43)	4.50[b] (4.43-4.57)	4.81[a] (4.71-4.86)	3.78[c] (3.71-3.86)
Total score	17.50[d] (17.29-17.70)	20.14[b] (20.00-20.28)	21.17[a] (21.14-21.28)	18.89[c] (18.71-19.00)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.05$).

Table 23. Instrumental texture profie of dudh as influenced by sugar level in milk used for cooking

Attributes	Sugar (%) 0	1.0	2.0	3.0
Hardness (N)	293.25^{c} (283.00-312.00)	325.50^{b} (321.00-332.00)	361.75^{a} (354.00-372.00)	329.00^{b} (309.00-340.00)
Cohesiveness	0.53^{b} (0.52-0.54)	0.55^{b} (0.53-0.58)	0.59^{a} (0.57-0.62)	0.58^{a} (0.56-0.60)
Springiness (mm)	0.63^{b} (0.60-0.65)	0.69^{ab} (0.65-0.75)	0.71^{a} (0.65-0.75)	0.74^{a} (0.70-0.80)
Gumminess (N)	154.64^{c} (147.68-162.24)	179.82^{b} (173.88-189.66)	213.52^{a} (204.63-230.64)	109.92^{b} (173.04-198.60)
Chewiness (N.mm)	96.54^{c} (93.49-99.33)	123.87^{b} (113.02-142.25)	152.14^{a} (133.01-161.45)	141.03^{ab} (121.13-158.88)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.05$).

Table 24. Intrinsic parameters of dudh churpi as influenced by sugar level in milk used for cooking

Parameters	Sugar (%)			
	0	1.0	2.0	3.0
Lactic acid (%)	0.04[a] (0.03-0.05)	0.04[a] (0.02-0.06)	0.04[a] (0.03-0.05)	0.05[a] (0.04-0.06)
Free fatty acid (as % oleic acid)	0.84[b] (0.82-0.86)	0.84[b] (0.82-0.88)	0.95[a] (0.93-0.97)	0.96[a] (0.93-0.99)
2-Thiobarbituric acid value (A_{530})	0.06[a] (0.03-0.09)	0.06[a] (0.05-0.07)	0.06[a] (0.05-0.07)	0.06[a] (0.05-0.07)
Tyrosine (mg/g)	0.15[a] (0.12-0.18)	0.15[a] (0.13-0.17)	0.16[a] (0.15-0.17)	0.16[a] (0.13-0.19)
Free HMF (μmol/g)	26.43[d] (26.40-26.46)	27.19[c] (27.15-27.23)	27.69[b] (27.63-27.77)	28.33[a] (28.28-28.35)
Total HMF (μmol/g)	49.19[d] (49.18-49.20)	56.01[c] (55.09-56.13)	59.11[b] (59.06-59.16)	61.28[a] (61.25-61.31)
p-DMAB reactivity (A_{545})	0.19[a] (0.17-0.21)	0.21[a] (0.19-0.23)	0.21[a] (0.19-0.23)	0.22[a] (0.21-0.23)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly (P<0.05).

Table 25. Sensory atributes of dudh churpi as influenced by total solids content of milk used for cooking

Attributes	Total solids (%) 11.70	15.60	23.40	29.25
Flavour	6.57^{d} (6.43-6.71)	7.35^{c} (7.28-7.43)	7.96^{b} (7.86-8.14)	8.35^{a} (8.28-8.43)
Body and texture	6.14^{c} (6.00-6.28)	7.57^{b} (7.43-7.71)	7.93^{a} (7.86-8.00)	8.00^{a} (7.86-8.14)
Colour and appearance	2.57^{d} (2.43-2.71)	3.14^{c} (3.00-3.28)	4.07^{b} (4.00-4.14)	4.81^{a} (4.71-4.86)
Total score	15.28^{d} (14.86-15.56)	18.07^{c} (17.86-18.42)	19.97^{b} (19.86-20.00)	21.17^{a} (21.14-21.28)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly (P<0.05).

Table 26. Instrumental texture profile of dudh churpi as influenced by total solids content of milk used for cooking

Attributes	Total solids (%) 11.70	15.60	23.40	29.25
Hardness (N)	301.25[c] (296.00-309.00)	312.75[b] (302.00-318.00)	355.50[a] (349.00-361.00)	361.75[a] (354.00-372.00)
Cohesiveness	0.47[b] (0.43-0.52)	0.54[a] (0.48-0.58)	0.57[a] (0.54-0.61)	0.59[a] (0.57-0.62)
Springiness (mm)	0.46[c] (0.45-0.50)	0.58[b] (0.55-0.60)	0.68[a] (0.65-0.70)	0.71[a] (0.65-0.75)
Gumminess (N)	141.52[c] (131.12-157.04)	168.77[b] (151.20-175.16)	202.75[a] (190.62-220.21)	213.52[a] (204.63-230.64)
Chewiness (N.mm)	65.34[c] (59.00-70.67)	97.20[b] (83.16-105.10)	137.14[a] (123.90-154.15)	152.14[a] (133.01-161.45)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.05$).

solids content for different periods. Scores on each sensory attribute increased significantly ($P<0.05$) with the increase in time of cooking upto a period of 15 min. There was no significiant ($P<0.05$) difference in flavour, body and texture scores of the samples of dudh churpi, cooked for 15 and 20 min, but the colour and appearance and total scores significantly ($P<0.05$) decreased (Table 27).

The mean values for all the instrumental parameters, except hardness and springiness, were significantly ($P<0.05$) higher in the samples of dudh churpi cooked in milk for 15 min. Hardness increased with the increase in cooking time up to 15 min, beyond which the increase was not significant ($P<0.05$). On the other hand, the increase in cohesiveness, gumminess and chewiness continued upto 15 min beyond which the values declined significantly ($P<0.05$) (Table 28).

4.3.3. Moisture level of prechurpi

Pieces of cooked and pressed green curd (4 cm x 2 cm x 1 cm) were smoked over wooden fire for 30 min and dried at different temperatures. The traditional drying over wooden fire was continued at an average temperature of 34°C. Three different drying chambers maintained at 35, 40 and 45°C were also used. Prechurpi samples having 40, 35, 30 and 25% moisture were cooked for 15 min in milk of 1.0% fat, 2.0% sugar and 29.25% total solids content, and further drying was continued under the same previous conditions of drying till the product attained a moisture content of 15.4%.

None of the samples cooked at 40, 35 and 25% moisture levels and dried at different temperatures met the quality requirements with respect to any sensory attribute (Table 29). Samples of dudh churpi, cooked at 30%

Table 27. Sensory atributes of dudh churpi as influenced by time of cooking prechurpi

Attributes	Cooking time (min)			
	5	10	15	20
Flavour	6.21^{c} (6.00-6.43)	6.57^{b} (6.43-6.71)	8.35^{a} (8.28-8.43)	8.24^{a} (8.14-8.28)
Body and texture	5.86^{c} (5.71-6.00)	7.75^{b} (7.57-7.86)	8.00^{a} (7.86-8.14)	8.07^{a} (8.00-8.14)
Colour and appearance	2.50^{d} (2.43-2.57)	2.85^{c} (2.71-3.00)	4.81^{a} (4.71-4.85)	4.57^{b} (4.43-4.70)
Total score	14.57^{d} (14.43-14.71)	17.17^{c} (17.13-17.29)	21.17^{a} (21.13-21.28)	20.88^{b} (20.71-21.12)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.05$).

Table 28. Instrumental texture profile of dudh churpi as influenced by time of cooking prechurpi

Attributes	Cooking time (min)			
	5	10	15	20
Hardness (N)	323.25^{c} (320.00-326.00)	333.00^{b} (330.00-336.00)	361.75^{a} (354.00-372.00)	368.00^{a} (366.00-369.00)
Cohesiveness	0.47^{c} (0.45-0.49)	0.48^{c} (0.47-0.49)	0.59^{a} (0.57-0.62)	0.55^{b} (0.51-0.58)
Springiness (mm)	0.45^{b} (0.40-0.50)	0.48^{b} (0.45-0.50)	0.71^{a} (0.65-0.75)	0.71^{a} (0.70-0.75)
Gumminess (N)	151.96^{c} (144.90-159.25)	159.83^{c} (157.45-161.70)	213.52^{a} (204.63-230.64)	200.57^{b} (188.19-214.02)
Chewiness (N.mm)	68.35^{c} (58.88-72.45)	75.91^{c} (71.49-80.64)	152.14^{a} (133.01-166.45)	142.82^{b} (131.73-149.81)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.05$).

Table 29. Effect of different moisture levels of prechurpi for cooking and different drying temperatures on sensory quality of dudh churpi

Moisture (%)	Drying temperature (°C)	Sensory score: Flavour	Body and texture	Colour and appearance	Total score
40	T*	4.61 (4.43-4.71)	5.04 (4.86-5.14)	2.28 (2.14-2.43)	11.92 (11.71-12.14)
	35	4.79 (4.71-4.86)	5.11 (5.00-5.14)	2.32 (2.14-2.43)	12.21 (11.86-12.43)
	40	4.28 (4.14-4.43)	4.79 (4.71-4.86)	2.07 (2.00-2.14)	11.14 (11.00-11.43)
	45	4.36 (4.28-4.43)	4.50 (4.43-4.57)	1.90 (1.86-2.00)	10.75 (10.71-10.86)
35	T*	7.28 (7.14-7.43)	6.97 (6.86-7.14)	3.43 (3.28-3.57)	17.68 (17.43-17.86)
	35	7.32 (7.14-7.43)	7.04 (6.86-7.14)	3.46 (3.28-3.57)	17.82 (17.28-18.14)
	40	7.07 (7.00-7.14)	6.21 (6.14-6.28)	3.36 (3.28-3.57)	16.64 (16.57-16.71)
	45	6.79 (6.71-6.86)	5.97 (5.86-6.14)	2.21 (2.14-2.28)	14.96 (14.71-15.14)

Table 29. Continued

Moisture (%)	Drying temperature (°C)	Sensory score			
		Flavour	Body and texture	Colour and appearance	Total score
30	T*	8.36 (8.28-8.43)	8.00 (7.86-8.14)	4.82 (4.71-4.86)	21.18 (21.14-21.28)
	35	8.28 (8.14-8.43)	8.07 (7.86-8.28)	4.79 (4.71-4.86)	21.14 (21.00-21.28)
	40	7.90 (7.86-8.00)	7.69 (7.63-7.71)	3.79 (3.71-3.86)	19.37 (19.28-19.57)
	45	7.47 (7.43-7.57)	7.50 (7.43-7.57)	3.21 (3.14-3.28)	18.18 (18.00-18.28)
25	T*	7.50 (7.43-7.57)	7.25 (7.14-7.43)	3.47 (3.43-3.57)	18.21 (18.00-18.28)
	35	7.54 (7.43-7.71)	7.32 (7.14-7.43)	3.47 (3.43-3.57)	18.32 (18.00-18.43)
	40	6.97 (6.86-7.14)	6.68 (6.57-6.71)	2.61 (2.43-2.57)	16.25 (16.00-16.56)
	45	6.75 (6.71-6.86)	6.39 (6.28-6.43)	2.11 (2.00-2.14)	15.24 (15.00-15.43)
CD (P<0.05)		0.14	0.15	0.14	0.28

Data represent the means of four replicates. Ranges are given in parentheses.
*T. the traditional process of drying. temperature varied from maximum 44°C to minimum 26°C

moisture level and dried by traditional way and at 35 and 40°C, scored above the acceptable values. There was no significant ($P<0.05$) difference in quality of the product cooked at 30% moisture level and dried at traditional method and 35°C (Table 29 and Figs 5-8). Statistical analysis of the processing factors (Table 30) showed that the interactions among moisture levels, drying temperatures and in between moisture levels and drying temperatures were hightly significant ($P<0.01$) for all the sensory attributes studied.

4.3.4. Drying behaviour of cooked prechurpi

The plots of moisture ratio versus time of drying under four different temperatures and with three different sizes of dudh churpi are shown in Figs 9-12. The data on drying behaviour were recorded only after cooking prechurpi of 30% moisture level in milk of 1.0% fat, 2.0% sugar and 29.25% total solids content for 15 min. Maximum and minimum drying temperatures and relative humidities at different days of traditional drying are presented in Table 31. The rate of reduction in moisture ratio was less in the samples of larger sizes under all temperature conditions (Fig 9-12). The rate of drying was decreased with the time of drying. The miosture contentvariation during drying was monitored by the formula of material balance $Q_1(100 - M_1) = Q_2(100 - M_2)$, where, Q_1 and Q_2 are initial and final weights in g and M_1 and M_2 are moisture contents at Q_1 and Q_2. The rate of drying was expressed by the model (Page 1949):

$$MR = \frac{M_t - M_e}{M_o - M_e} = \exp(-k_1 t^{k_2})$$

Where, M_t is the moisture content at time t, M_e is the equilibrium moisture

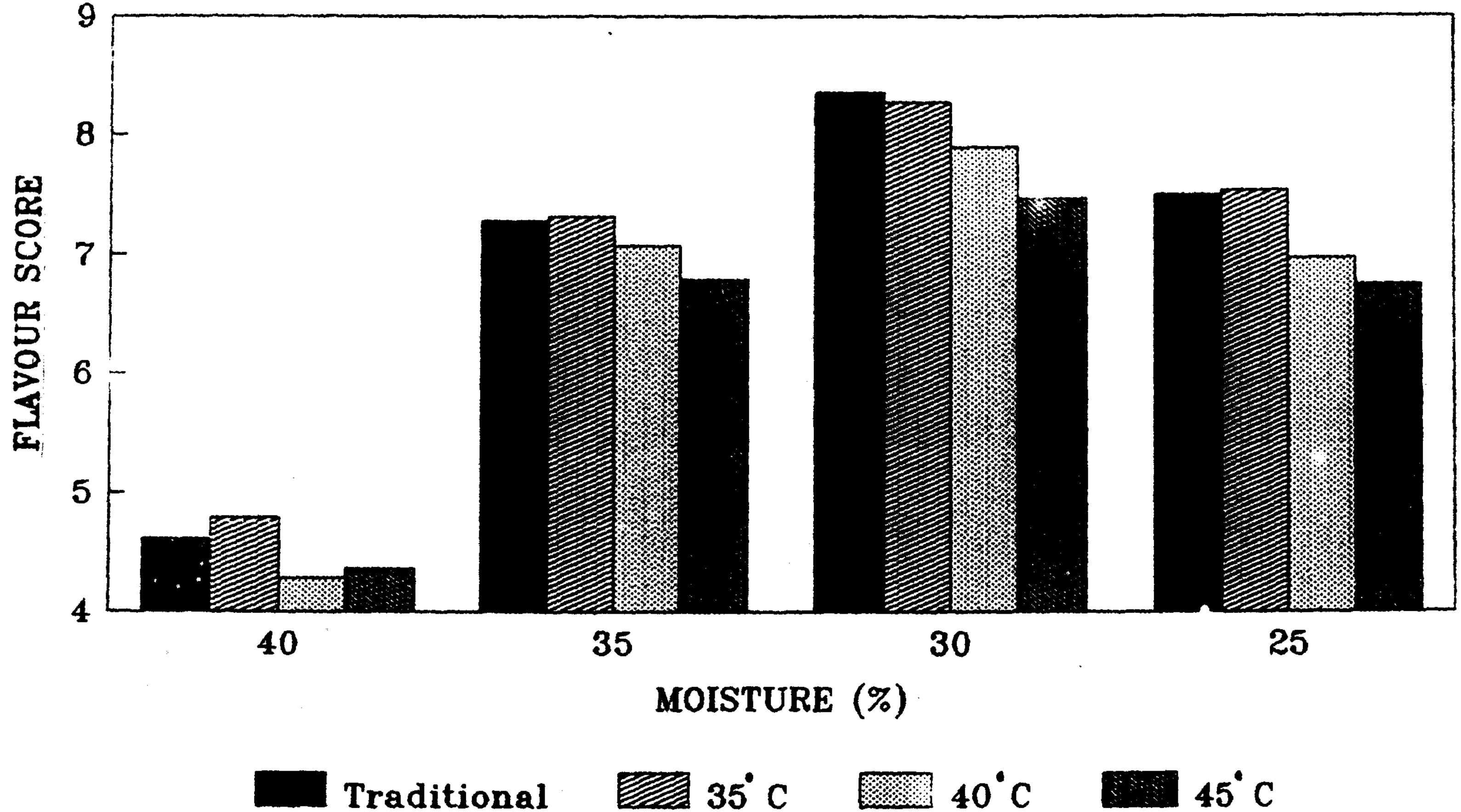

Fig. 5. Flavour scores of dudh churpi as influenced by diffrent moisture levels used for cooking prechurpi dried at diffrent temperatures

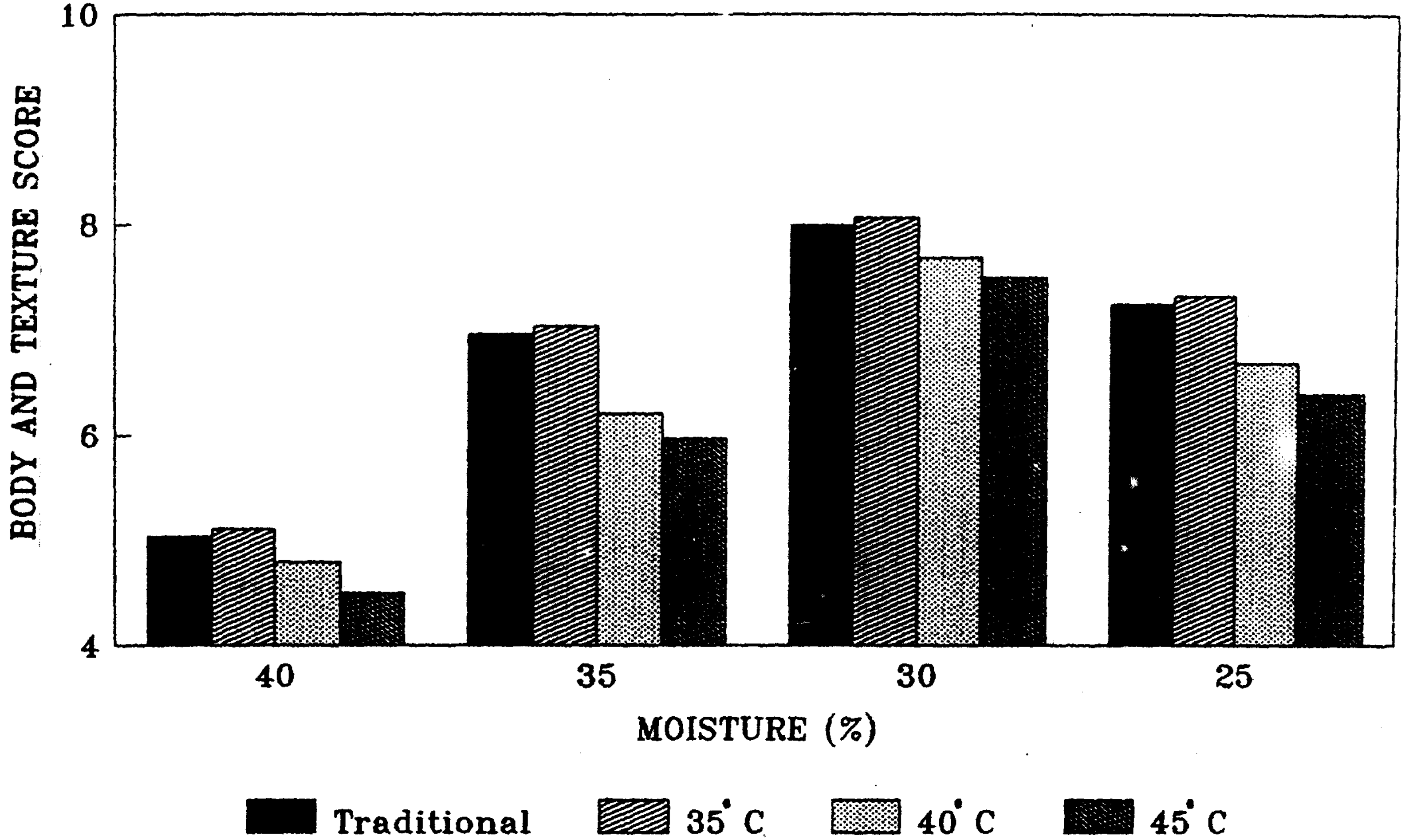

Fig. 6. Body and texture scores of dudh churpi as influenced by diffrent moisture levels used for cooking prechurpi and dried at diffrent temperatures

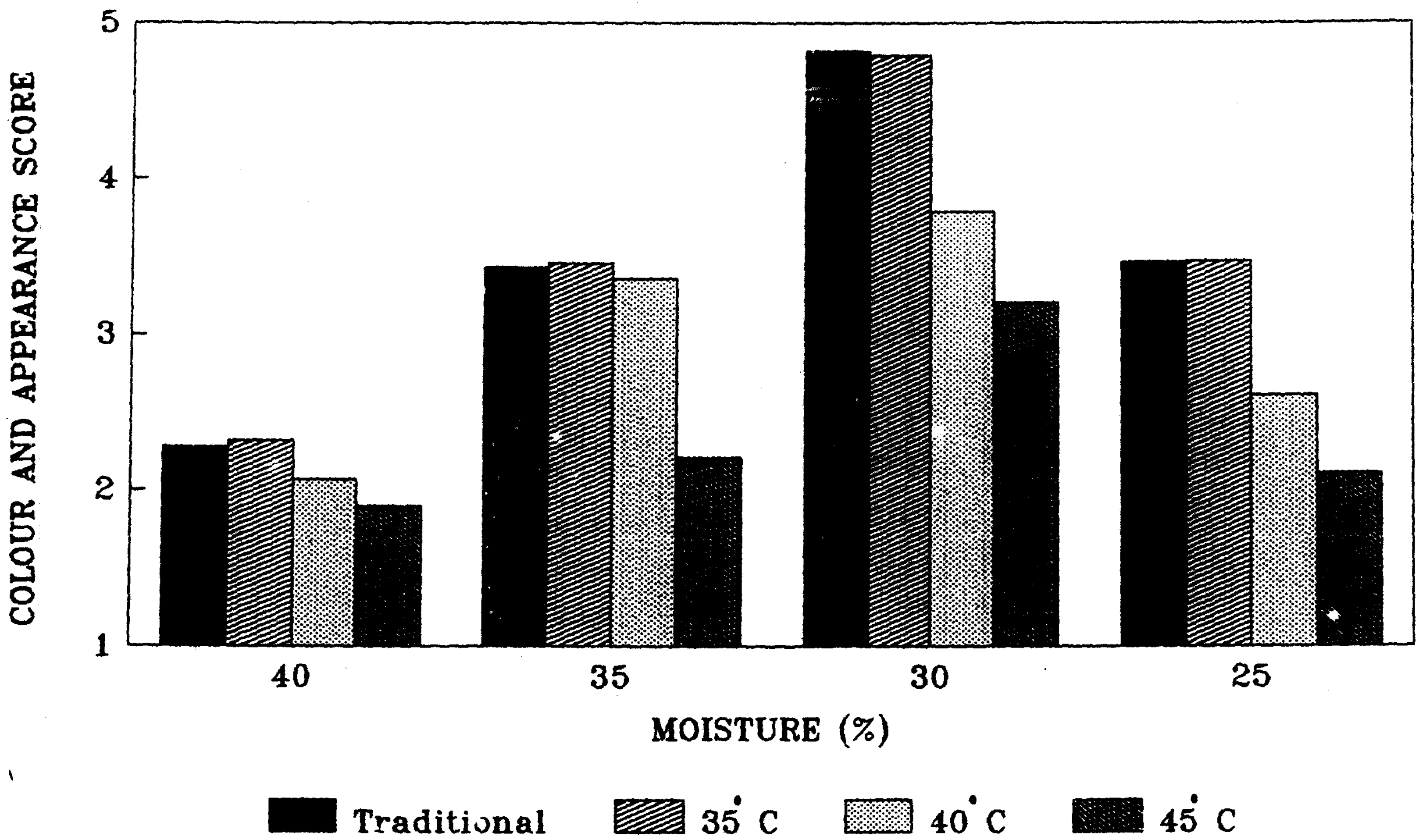

Fig.7. Colour and appearance scores of dudh churpi as influenced by diffrent moisture levels used for cooking prechurpi and dried at diffrent temperatures

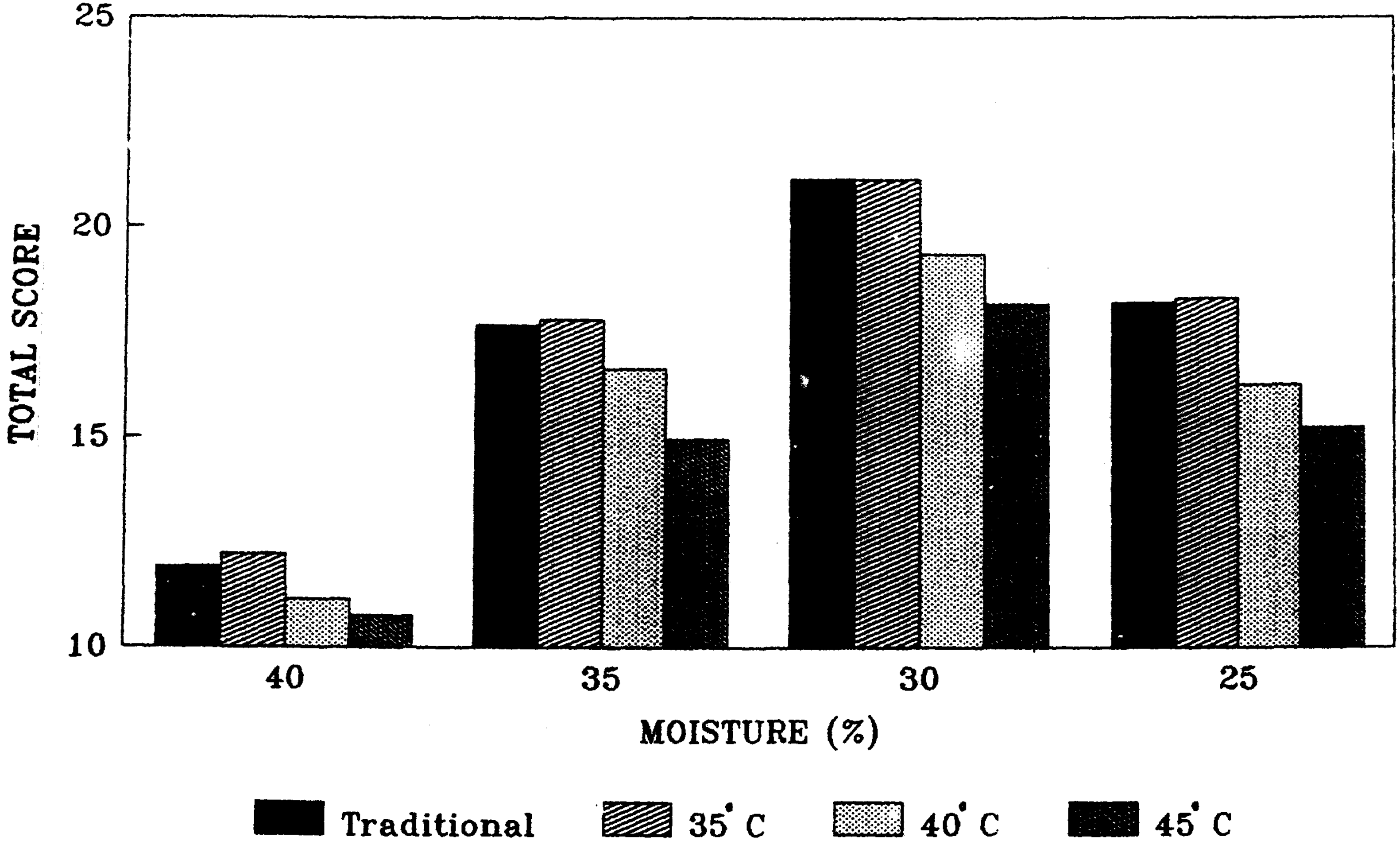

Fig.8. Total scores of dudh churpi as influenced by diffrent moisture levels used for cooking prechurpi and dried at diffrent temperatures

Table 30. Analysis of variance for sensory attributes of dudh churpi cooked at different moisture levels and dried at different temperatures

Source of variation	Degrees of freedom	Mean sum of squares*			
		Flavour	Body and texture	Colour and appearance	Total score
Among moisture levels (M)	3	36.837	24.513	10.967	198.103
Among drying temperatures (T)	3	1.529	2.313	4.803	24.276
Interaction (M x T)	9	0.071	0.078	0.373	0.731
Error	45	0.010	0.012	0.010	0.039

* Significant at $P<0.01$

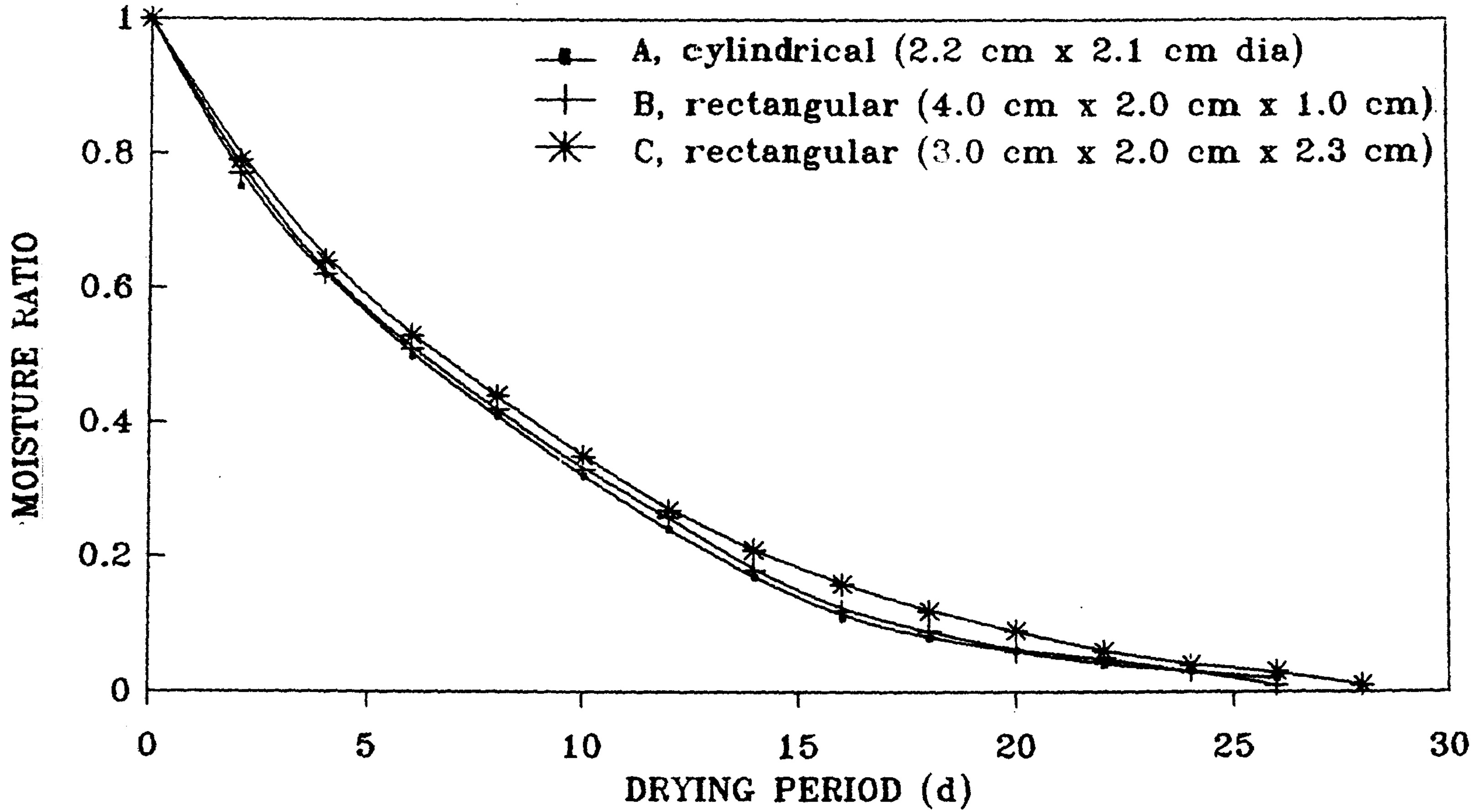

Fig. 9. Effect of size and period of drying at traditional drying on drying behaviour of dudh churpi

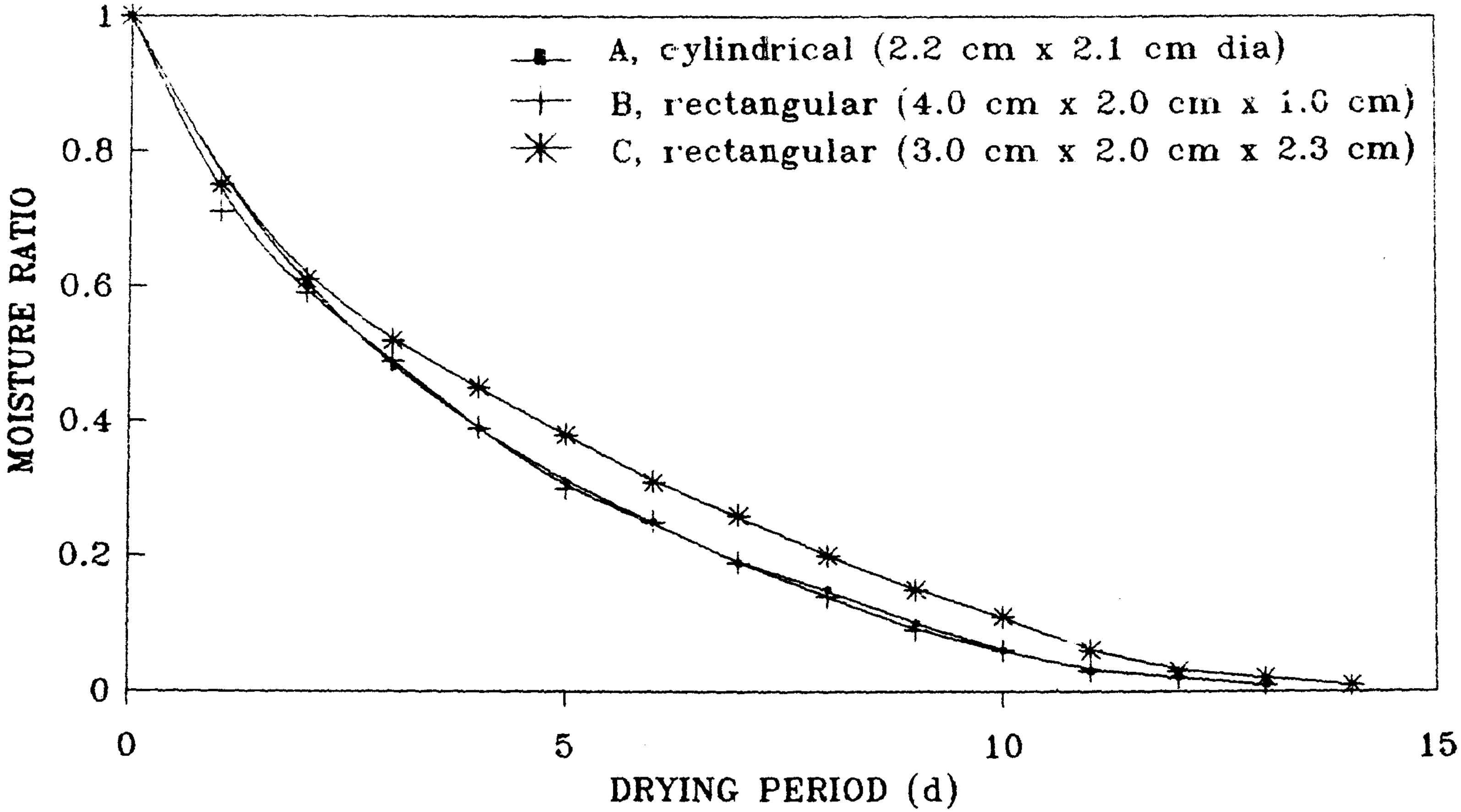

Fig. 10. Effect of size and period of drying at 35°C on drying behaviour of dudh churpi

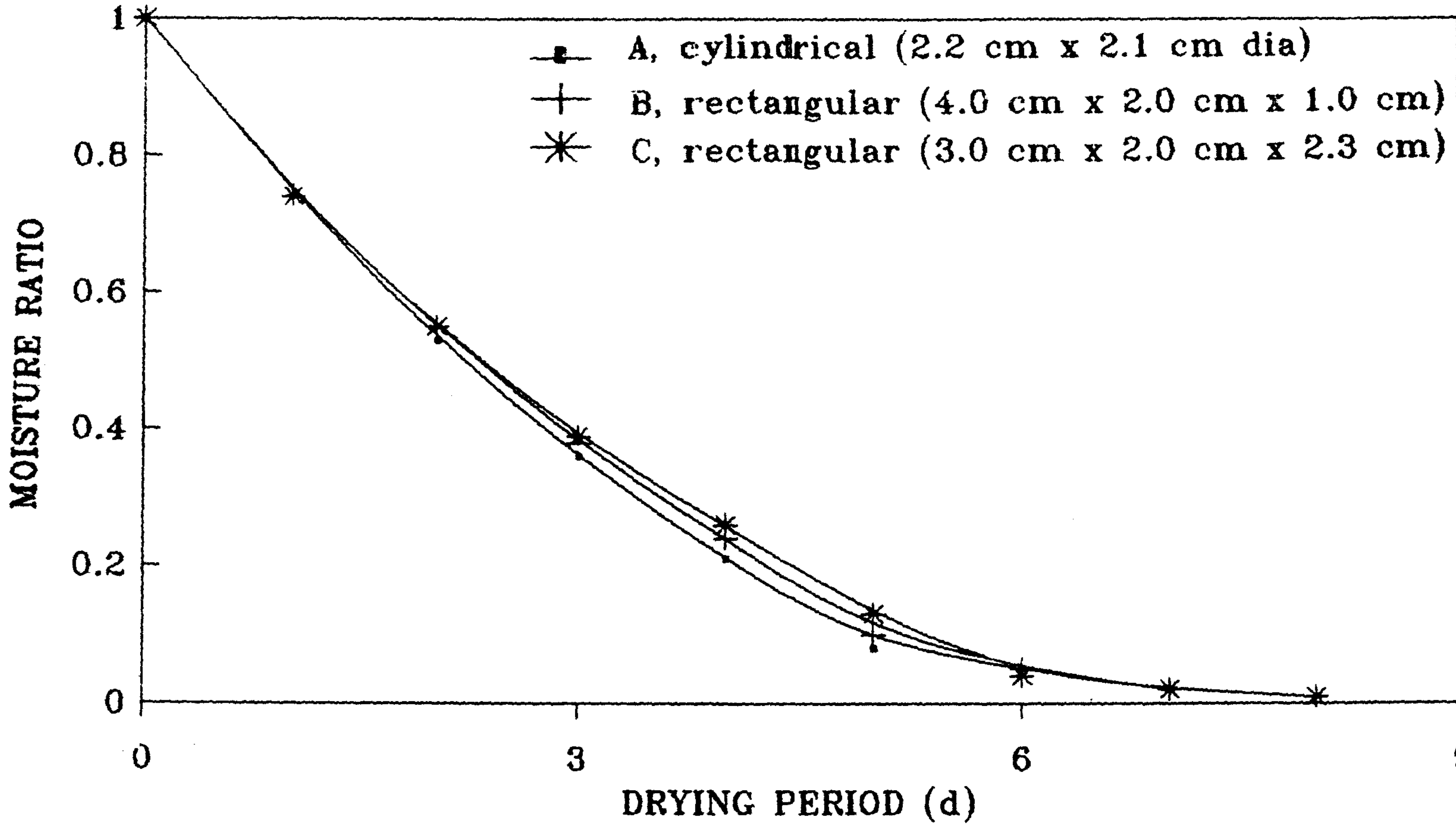

Fig. 12. Effect of size and period of drying at 45°C on drying behaviour of dudh churpi

Table 31. Maximum and minimum temperatures and relative humidities at different days of traditional drying

Day	Relative humidity (%)		Temperature (oC)	
	Maximum	Minimum	Maximum	Minimum
0	67.0	36.0	41.0	27.5
2	63.0	32.0	40.0	26.5
4	64.0	29.0	38.0	27.5
6	65.0	36.0	42.0	28.0
8	65.0	31.0	43.0	27.0
10	66.6	31.5	40.5	26.5
12	65.7	39.0	41.5	26.5
14	66.0	37.0	39.5	27.5
16	65.6	36.0	42.5	28.0
18	66.0	34.0	43.0	29.5
20	62.0	33.0	41.5	28.0
22	64.0	32.0	43.0	32.0
24	63.0	31.5	41.0	28.0
26	61.0	32.0	42.0	27.0
28	66.0	35.0	39.0	26.0
30	61.0	29.0	44.0	30.5
32	63.0	28.0	41.0	26.5
34	64.0	27.0	40.0	26.0
36	60.0	28.0	38.0	27.0

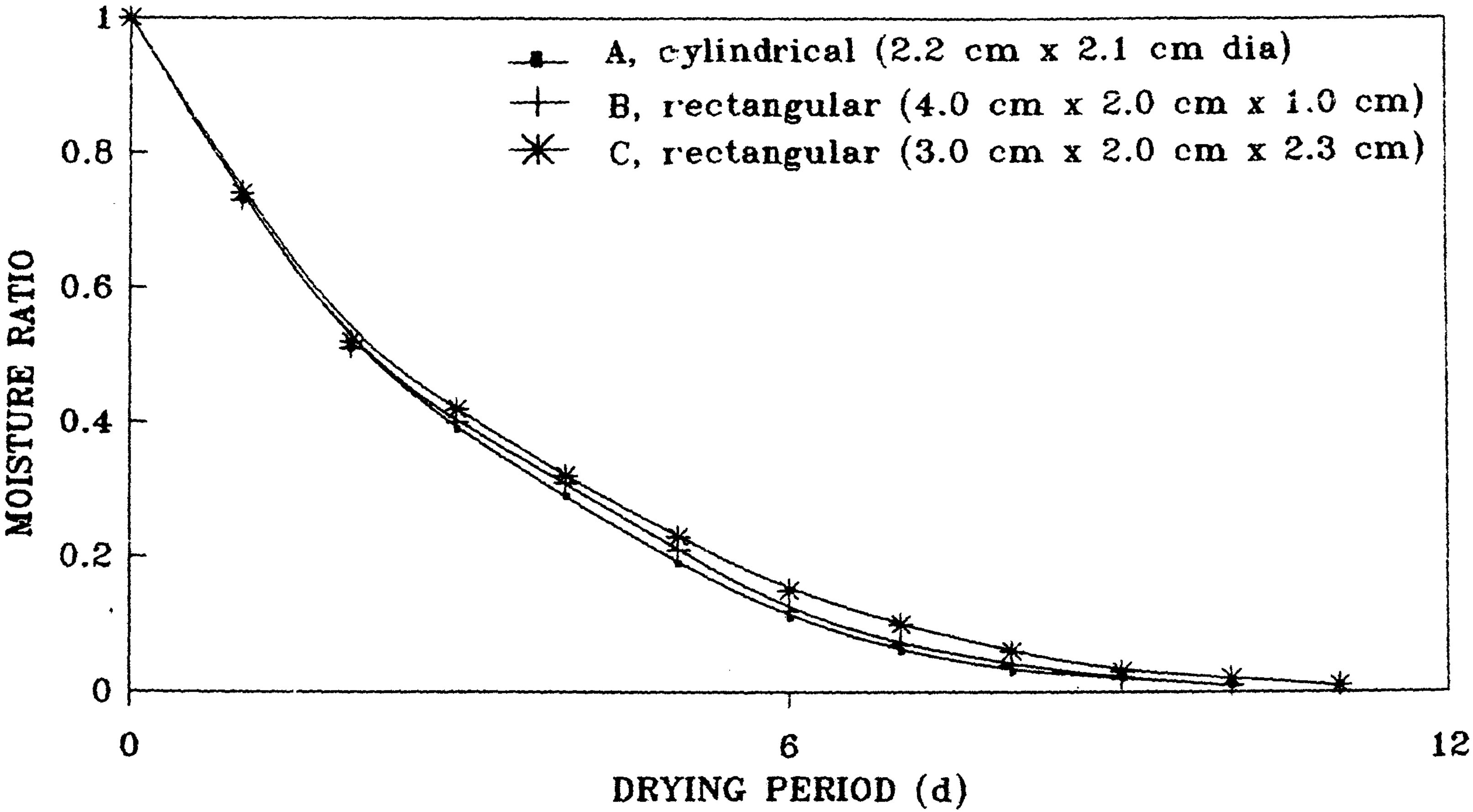

Fig. 11. Effect of size and period of drying at 40°C on drying behaviour of dudh churpi

content and M_0 is the initial mositure content. The constants k_1 and k_2 are found to depend upon temperature and relative humidity. These constants can be expressed in the form:

$$k_1 = 0.389 - 0.11T + 0.002RH$$
$$k_2 = 0.267 + 0.02T + 0.002RH$$

where, T denotes temperature in °C and RH denotes relative humidity. The effects of size on the rate of drying of dudh churpi at different temperatures can be evaluated by considering the time of half-response ($t_{1/2}$). The $t_{1/2}$ is defined as the time required to remove the first half of the free moisture. This corresponds to the time required to reach a miosture ratio of 0.5. Drying eqations, $t_{1/2}$ and predicted drying period (days) as evaluated by the Page's model with percent root mean square (% RMS), are presented in Table 32 This shows that rate of drying was higher for smaller sizes of dudh churpi and the drying rate increased with the increase in temperature. The fitness of Page equation to the data was tested by calculating the %RMS which lies between 1.26-1.62 in case of traditional drying and between 3.78-5.92, 0.99-1.86 and 0.76-1.65 during drying at 35, 40 and 45°C, respectively. These low % RMS suggest that the Page model fit well to the data.

The Instron texture profile of dudh churpi of three different sizes dried at four different temperatures is shown in Table 33.

Increase in temperature beyond 35° C adversely effected the Instron parameters, but no significant (P<0.01) difference with respect to size and temperature was observed when the samples of dudh churpi dried traditionally and in drying chamber at 35°C.

No significant (P<0.01) differences of Instron parameters were observed among sizes of dudh churpi and the interactions between size and temperature

Table 32. Drying behaviour of dudh churpi evaluated from Page's model

Drying temperature (oC)	Size*	Equations developed	Coefficient of correlation	Time of half response ($t_{1/2}$) (d)	Drying time (d)	RMS (%)
Traditional	A	$MR = e^{-0.113t^{1.059}}$	0.993	5.526	33.03	1.26
	B	$MR = e^{-0.103t^{1.087}}$	0.992	5.753	32.82	1.62
	C	$MR = e^{-0.093t^{1.095}}$	0.994	6.235	35.11	1.34
35	A	$MR = e^{-0.237t^{1.072}}$	0.982	2.721	15.92	3.78
	B	$MR = e^{-0.253t^{1.049}}$	0.977	2.607	15.85	4.90
	C	$MR = e^{-0.220t^{1.036}}$	0.974	3.021	18.78	5.92
40	A	$MR = e^{-0.281t^{1.179}}$	0.992	2.148	10.71	1.21
	B	$MR = e^{-0.284t^{1.139}}$	0.993	2.190	11.54	0.99
	C	$MR = e^{-0.270t^{1.140}}$	0.989	2.284	12.02	1.86
45	A	$MR = e^{-0.269t^{1.338}}$	0.993	2.025	8.34	0.76
	B	$MR = e^{-0.258t^{1.340}}$	0.990	2.087	8.27	1.10
	C	$MR = e^{-0.248t^{1.378}}$	0.987	2.109	8.33	1.65

*A, cylindrical (2.2 cm x 2.1 cm dia)
B. rectangular (4.0 cm x 2.0 cm x 1.0 cm)
C. rectangular (3.0 cm x 2.0 cm x 2.3 cm)

Table 33. Effect of size and drying temperature on Instron parameters of dudh churpi

Drying temperature (°C) (T)	Sizes (S)	Instron parameters: Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (N.mm)
Traditional	A	363.00 (354.00-372.00)	0.59 (0.57-0.62)	0.68 (0.60-0.75)	214.30 (201.78-230.64)	145.21 (123.89-172.98)
	B	362.00 (355.00-371.00)	0.60 (0.58-0.62)	0.71 (0.65-0.75)	216.33 (208.80-230.02)	153.79 (149.51-157.47)
	C	365.25 (358.00-370.00)	0.61 (0.59-0.63)	0.69 (0.65-0.75)	222.55 (211.22-232.47)	153.23 (137.29-174.35)
35	A	364.00 (356.00-368.00)	0.60 (0.58-0.63)	0.73 (0.70-0.75)	218.33 (211.70-224.28)	158.24 (151.57-165.60)
	B	364.75 (359.00-370.00)	0.62 (0.61-0.63)	0.68 (0.65-0.70)	224.29 (220.21-228.78)	151.39 (143.14-158.32)
	C	365.00 (355.00-371.00)	0.61 (0.58-0.63)	0.73 (0.70-0.75)	221.63 (204.60-225.68)	160.72 (150.22-167.74)
40	A	374.50 (371.00-376.00)	0.61 (0.59-0.63)	0.54 (0.50-0.60)	229.38 (221.84-236.88)	123.33 (110.92-139.50)
	B	373.50 (371.00-374.00)	0.60 (0.58-0.63)	0.58 (0.55-0.60)	224.41 (216.34-233.73)	129.11 (118.99-140.24)

Table 33. Continued

Drying temperature (°C) (T)	Sizes (S)	Instron parameters: Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (N.mm)
40	C	375.00 (374.00-376.00)	0.62 (0.60-0.63)	0.56 (0.50-0.60)	230.62 (225.00-235.62)	129.58 (117.81-137.62)
	A	402.50 (398.00-406.00)	0.43 (0.40-0.46)	0.35 (0.30-0.40)	173.15 (159.20-186.76)	60.95 (47.76-74.70)
45	B	404.25 (399.00-408.00)	0.44 (0.42-0.45)	0.36 (0.30-0.40)	175.82 (171.36-181.35)	63.60 (54.41-70.00)
	C	403.75 (400.00-407.00)	0.43 (0.40-0.46)	0.38 (0.35-0.40)	173.67 (160.00-186.76)	65.12 (59.09-74.70)
CD (P<0.05)		7.62	0.01	0.06	6.76	14.87
CD (P<0.01)		10.24	0.01	0.08	9.08	19.98

Data represent the means of four replicates. Ranges are given in parentheses.

* Variable temperature, temperature varied from maximum 44°C to minimum 26°C

conditions. But, the products prepared under different temperatures differed significantly ($P<0.01$) (Table 34).

4.4. Packaging and storage studies of dudh churpi

Fresh samples of dudh churpi, prepared under optimized conditions were packed in different containers as described in section 3.2.8. and stored at ambient temperatures.

4.4.1. Changes in sensory attributes

4.4.1.1. Flavour

The flavour scores of control samples (P_1B: without packaging and preservative) decreased with the increase in storage period (Table 35 and Fig.13). Throughout the storage period, flavour score of the samples treated with 0.01% sorbate and stored in glass containers remained at the minimum level (8.46-8.04).

4.4.1.2. Body and texture

Least change in the body and texture score (8.36-7.93) was observed in the samples of dudh churpi treated with 0.1% sorbate and packed in glass container (Table 35 and Fig. 14).

Table 34. Analysis of variance for Instron parameters of dudh churpi of different sizes and dried at different temperatures

Source of variation	Degrees of freedom	Mean sum of squares				
		Hardness (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (N.mm)
Among sizes (S)	3	8.7233	0.000130	0.00070	29.75	72.96
Among drying temperatures (T)	3	4159.25*	0.091000*	0.30670*	7197.15*	21975.85*
Interaction (S x T)	9	4.0000	0.000122	0.00130	25.81	31.63
Error	33	28.0478	0.000040	0.00182	22.09	106.83

*Significant at P<0.01

Table 35. Mean sensory scores of dudh churpi as influenced by type of packages, storage periods and preservatives

Stogare periods (months)	Packaging materials and forms**							
	P_1A	P_1B	P_2A	P_2B	P_3A	P_3B	P_4A	P_4B
				Flavour (10)				
0	8.46	8.46	8.46	8.46	8.46	8.46	8.46	8.46
1	8.07	8.43	8.36	8.43	8.04	8.25	8.00	8.21
2	7.11	8.14	8.21	8.25	7.86	8.07	8.00	8.21
3	6.14	8.04	8.07	8.21	7.86	8.07	7.82	8.04
4	5.07	7.64	7.79	8.11	7.68	7.86	7.61	8.00
5	4.60	7.28	7.82	8.11	7.21	7.78	7.54	7.86
6	3.50	5.61	7.79	8.04	7.07	7.75	6.79	7.68
				Body and texture(10)				
0	8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36
1	8.11	8.21	8.04	8.28	7.97	8.11	8.04	8.21
2	7.71	8.07	8.00	8.18	7.75	8.11	7.71	8.07
3	7.36	7.90	8.00	8.14	7.57	8.00	7.71	7.86
4	6.47	7.79	7.90	8.14	7.54	7.93	7.43	7.82
5	6.07	7.50	7.82	8.04	7.32	7.79	6.93	7.64
6	5.97	7.04	7.60	7.93	7.18	7.68	6.64	7.25
				Colour and appearance(05)				
0	4.79	4.79	4.79	4.79	4.79	4.79	4.79	4.79
1	4.64	4.75	4.64	4.75	4.64	4.75	4.68	4.64
2	3.64	4.64	4.54	4.64	4.39	4.64	4.36	4.39
3	2.79	4.50	4.36	4.64	4.21	4.47	4.11	4.39
4	2.32	4.07	4.32	4.54	4.18	4.47	3.79	4.10
5	1.93	3.75	4.25	4.36	3.90	4.18	3.61	3.93
6	1.47	3.50	4.11	4.25	3.79	4.11	3.36	3.86
				Total scores(25)				
0	21.61	21.61	21.61	21.61	21.61	21.61	21.61	21.61
1	20.82	21.39	21.03	21.46	20.64	21.10	20.71	21.06
2	18.46	20.85	20.75	21.06	20.00	20.82	20.07	20.67
3	16.28	20.43	20.43	20.99	19.64	20.54	19.64	20.29
4	13.86	19.50	20.00	20.78	19.39	20.25	18.82	20.00
5	12.61	18.53	19.89	20.50	18.43	19.74	18.07	19.43
6	10.93	16.14	19.57	20.21	18.03	19.53	16.78	18.79

* Mean of four replicates,

** P_1, without packaging; P_2, glass container; P_3, plastic container; P_4, plastic pouch; A, without sorbate and B, with 0.1% sorbate.

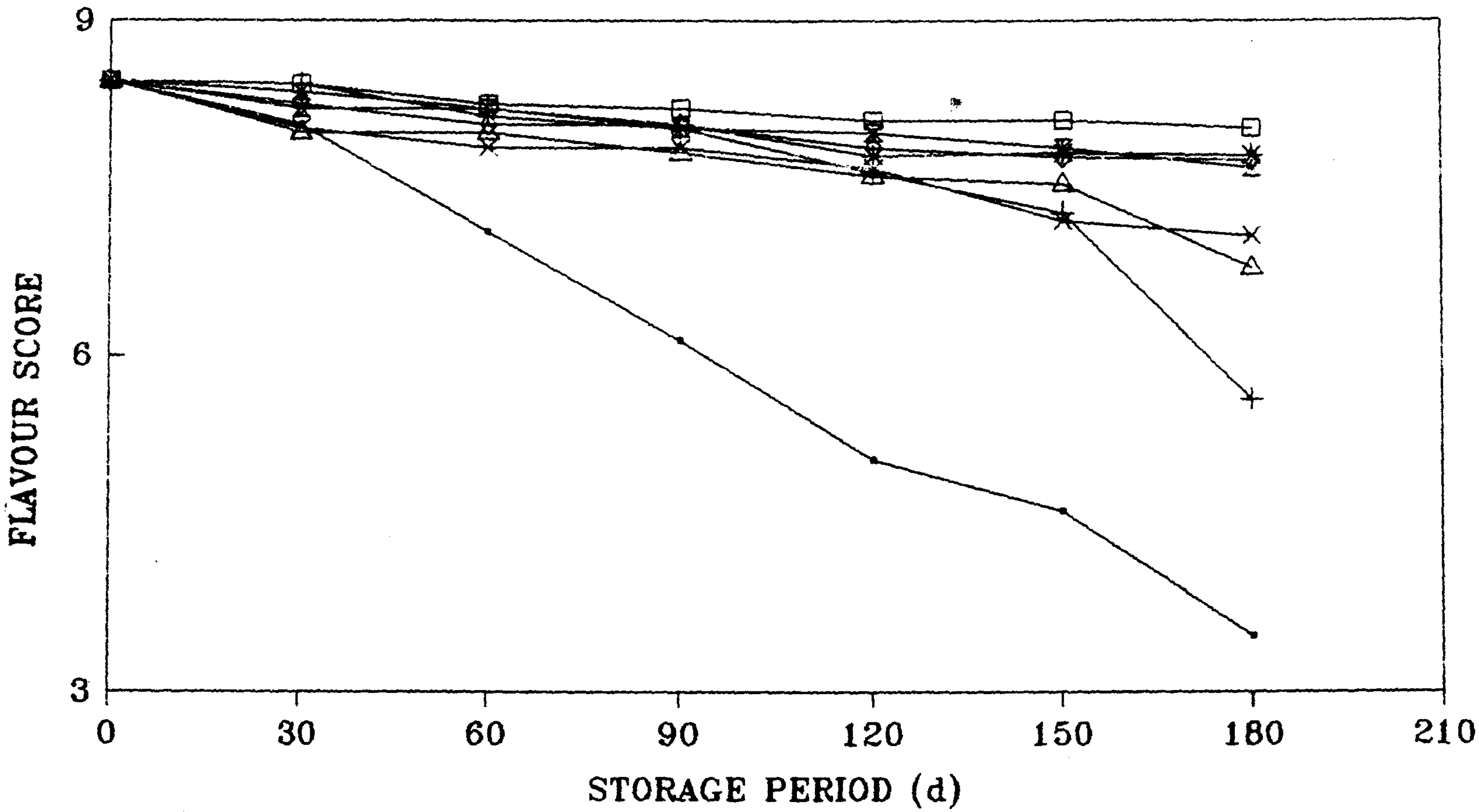

Fig. 13. Effect of packaging and storage on flavour scores of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

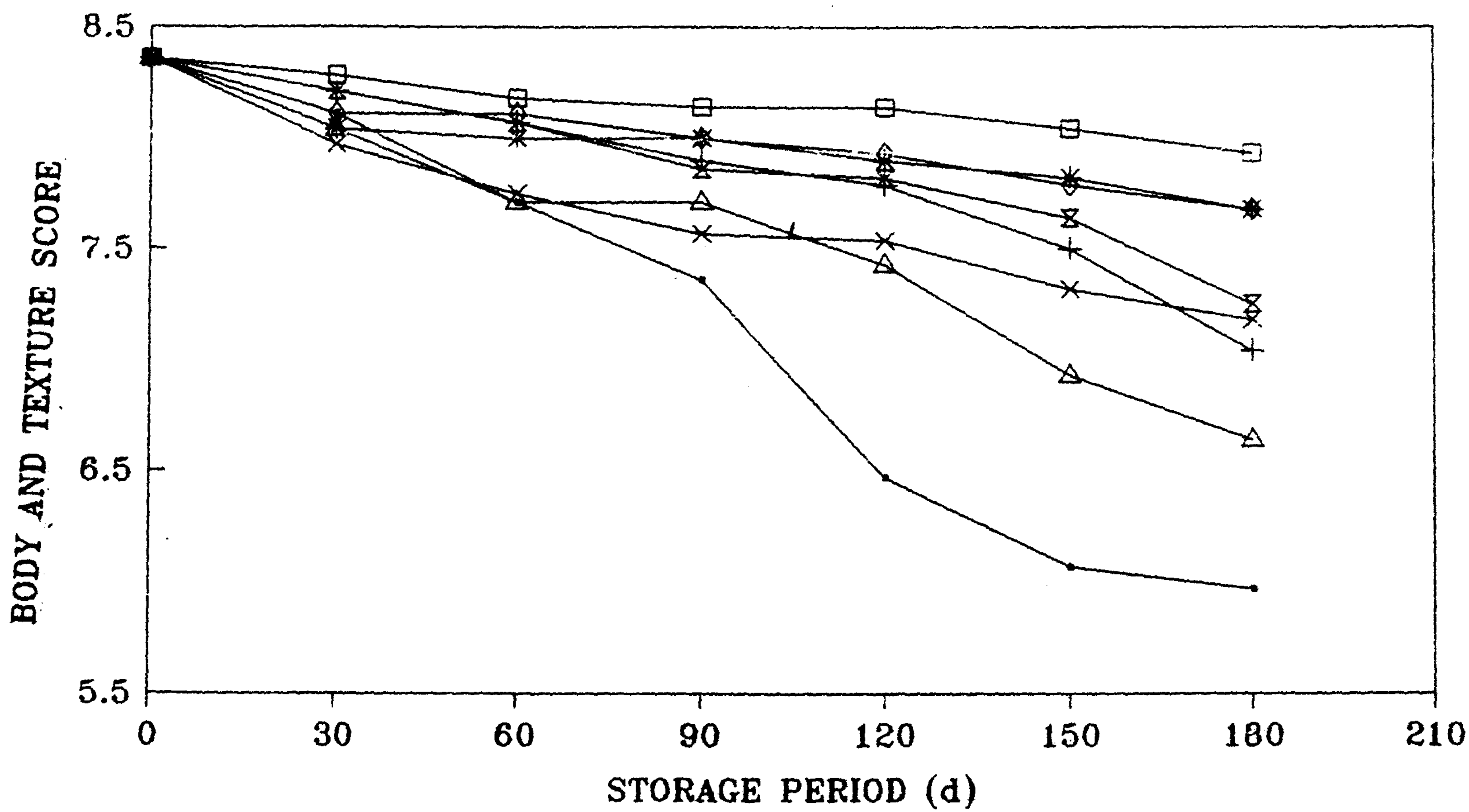

Fig. 14. Effect of packaging and storage on body and texure scores of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

4.4.1.3. Colour and appearance

Similar to the obsevations in flavour and body and texture scores, the changes in colour and appearance scores were also minimum (4.79-4.25) in the samples of dudh churpi treated with 0.1% sorbate and stored in glass containers (Table 35 and Fig. 15).

4.4.1.4. Total score

Since total score is the sum of all the individual sensory scores, the minimum change in total score (21.61-20.21) was observed in the samples of dudh churpi treated with 0.1% sorbate and stored in glass containers (Table 35 and Fig. 16).

4.4.1.5. Statistical significance of sensory data

Statistical analysis of the data (Table 35A) revealed that three types of packages and the control samples (without packages) two types of dudh churpi (with and without sorbate) and the duration of storage, all individually had a significant ($P<0.01$) influence on the sensory data of dudh churpi. Interactions between packages and intervals, intervals and types, packages and types. and packages, types and intervals were also significant ($P<0.01$).

4.4.2. Physico-chemical changes

4.4.2.1. Moisture

The adsorption of moisture in the samples of dudh churpi was maximum

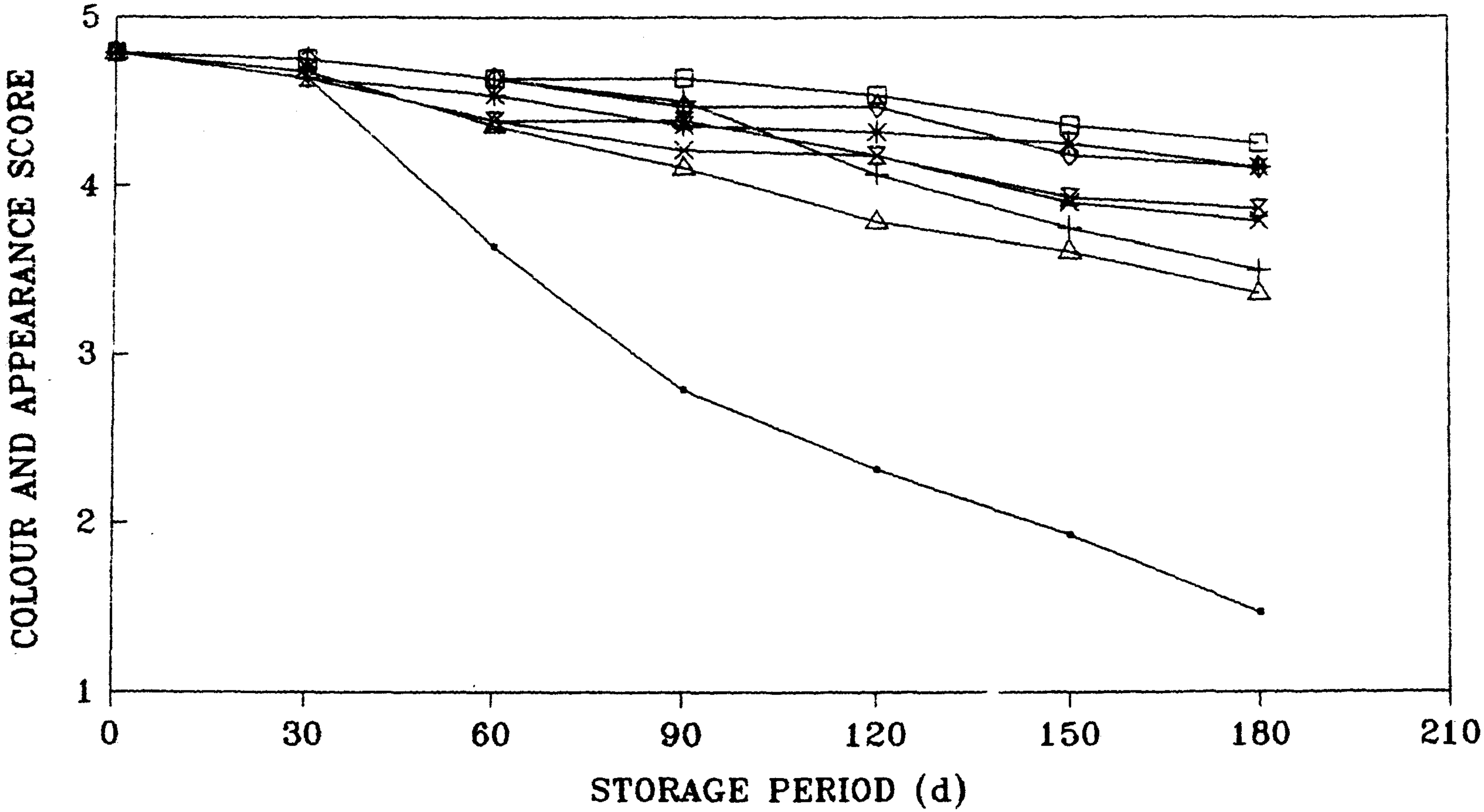

Fig. 15. Effect of packaging and storage on colour and appearance scores of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

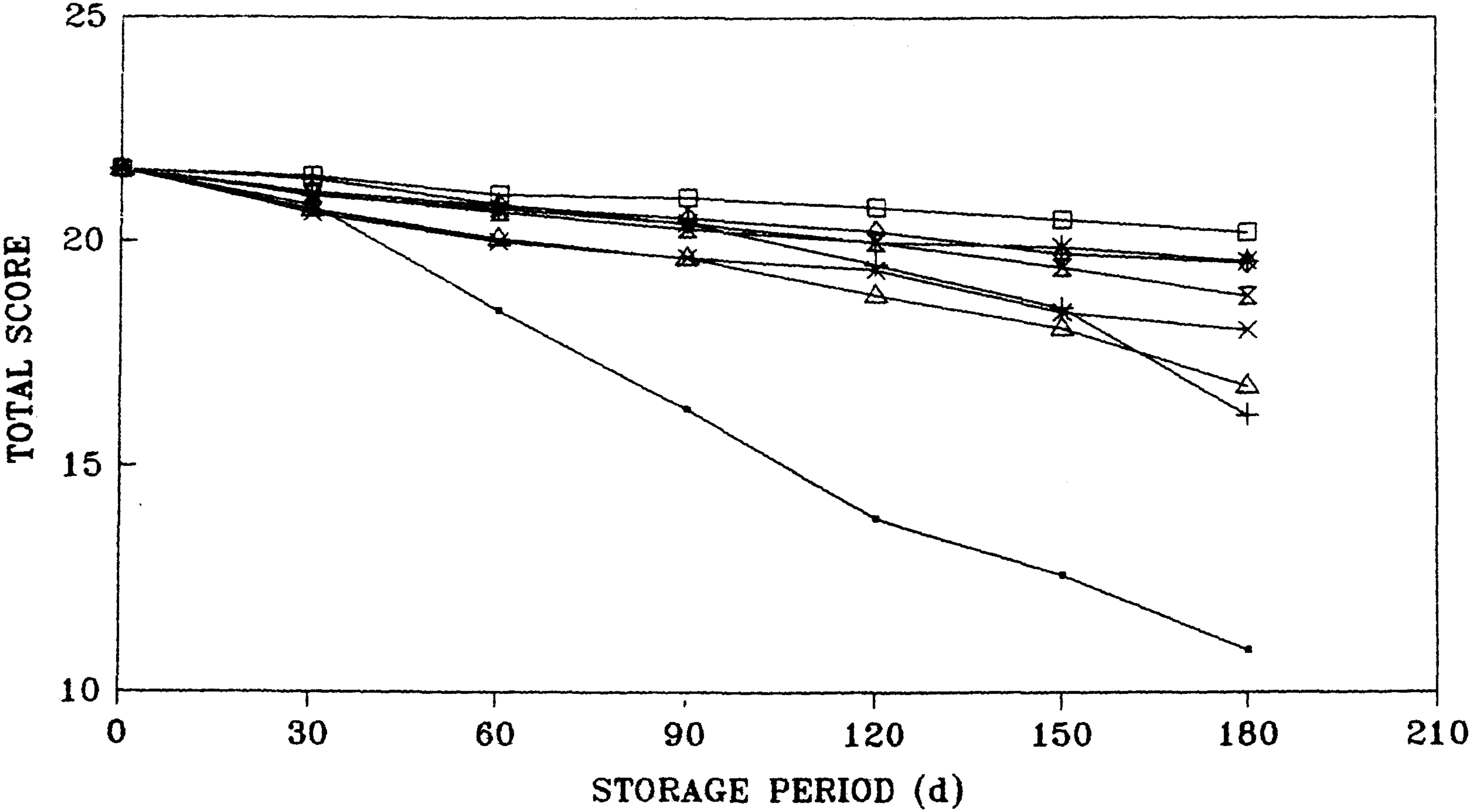

Fig. 16. Effect of packaging and storage on total scores of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

Table 35A. Analysis of variance for sensory attributes of dudh churpi during storage

Source of variation	Degrees of freedom	Flavour		Body and texture		Colour and appearance		Total score	
		MSS	CD	MSS	CD	MSS	CD	MSS	CD
Replicates	3	0.01		0.03		0.01		0.01	
Among packages (P)	3	17.24*	0.06	3.14*	0.06	7.19*	0.04	71.51*	0.10
Among storage periods (S)	6	10.81*	0.08	5.49*	0.08	6.94*	0.05	67.89*	0.13
Among preservatives (D)	1	18.42*	0.04	8.29*	0.04	10.97*	0.03	109.90*	0.07
Interactions:									
P x S	18	2.41*	0.16	0.46*	0.15	0.74*	0.11	8.98*	0.27
P x D	3	5.65*	0.08	0.65*	0.08	3.62*	0.06	25.63*	0.14
S x D	6	1.21*	0.11	0.53*	0.11	0.74*	0.08	6.97*	0.19
P x S x D	18	0.46*	0.22	0.12*	0.21	0.28*	0.15	2.17*	0.38
Error	165	0.015		0.014		0.007		0.043	

*Significant at P<0.01.
MSS; Mean sum of squares,
CD; Critical difference

(15.51-18.14) when stored traditionally and without any treatment with sorbate and was minimum (15.51-15.88) when treated with 0.1% potassium sorbate and stored in glass containers (Fig. 17).

4.4.2.2. Titratable acidity

An increase of 0.05% titratable acidity was observed when the samples were treated with 0.1% sorbate and kept in glass containers (Fig. 18). The rate of increase in acidity in all the cases was much higher when the samples were not treated with 0.1% sorbate.

4.4.2.3. Free fatty acid

Changes in free fatty acid profile were much more when the samples were not treated with 0.1% sorbate. Release of free fatty acid was controlled appreciably with the addition of sorbate (Fig. 19). Samples with sorbate and in glass containers showed the least (from initial 0.95 to 0.99 %) change in free fatty acid during the entire storage period.

4.4.2.4. Tyrosine value

Addition of sorbate inhibited the breakdown of proteins (Fig. 20). Samples with sorbate and in glass containers showed a negligible change during the storage period.

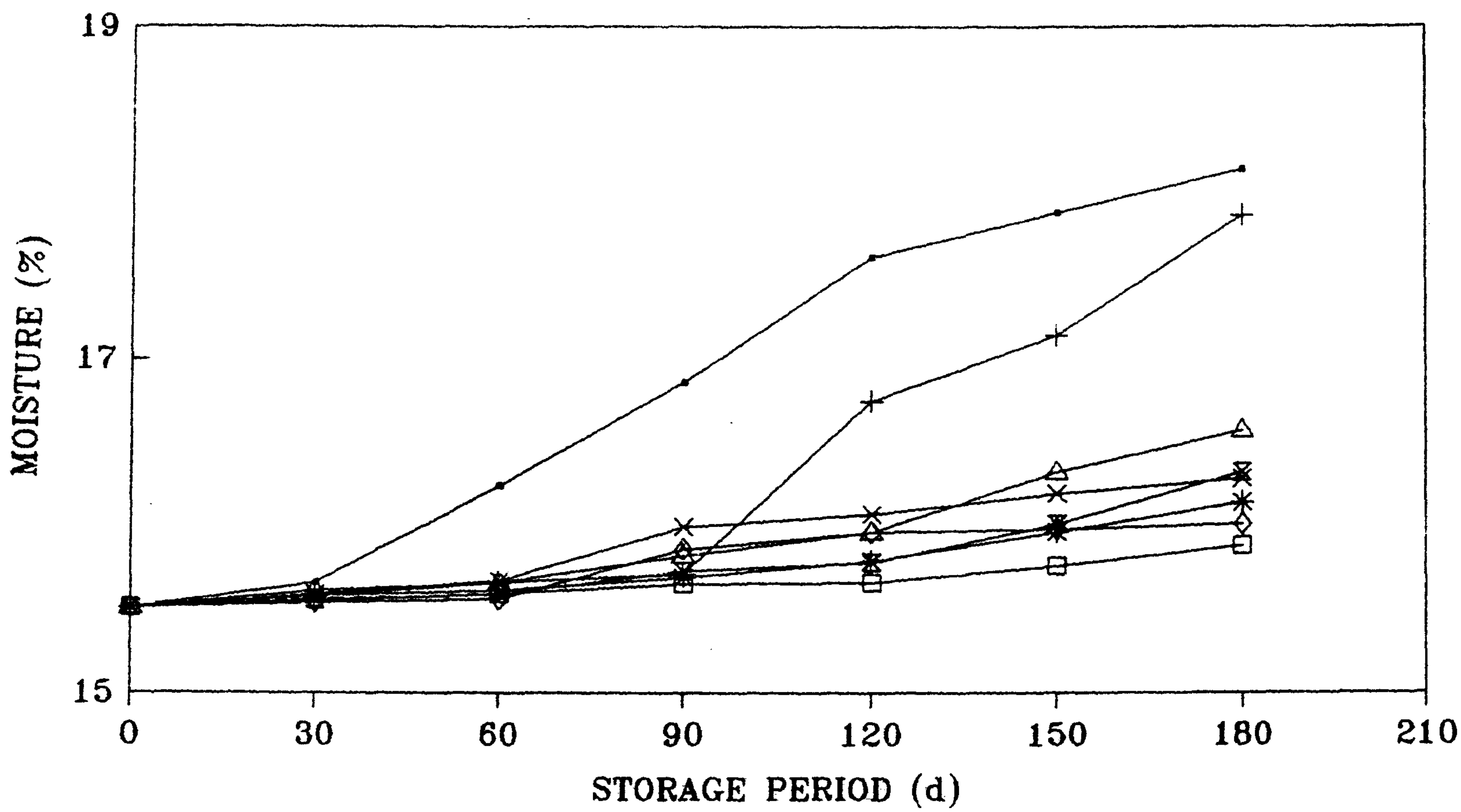

Fig. 17. Effect of packaging and storage on moisture of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

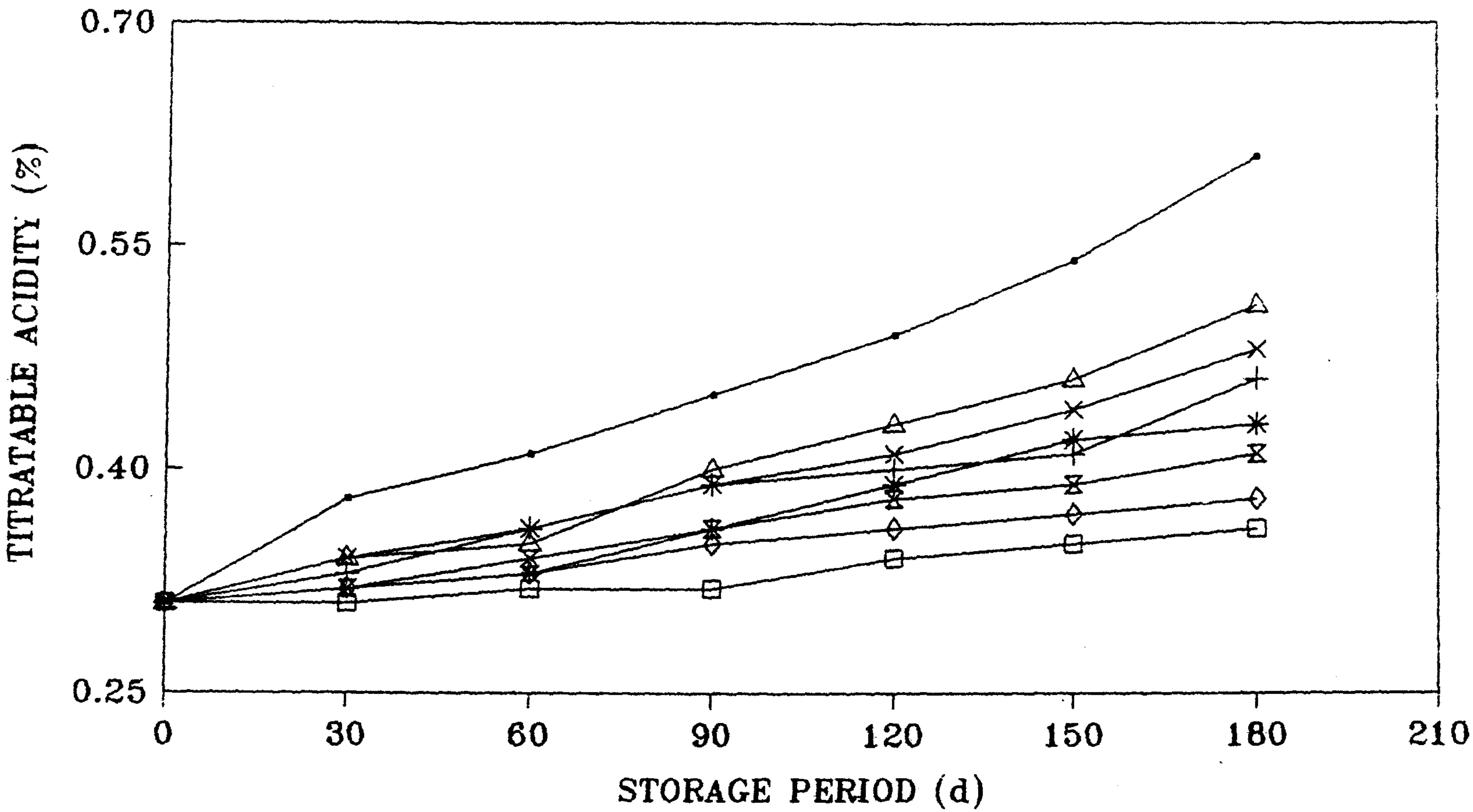

Fig. 18. Effect of packaging and storage on titratable acidity of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

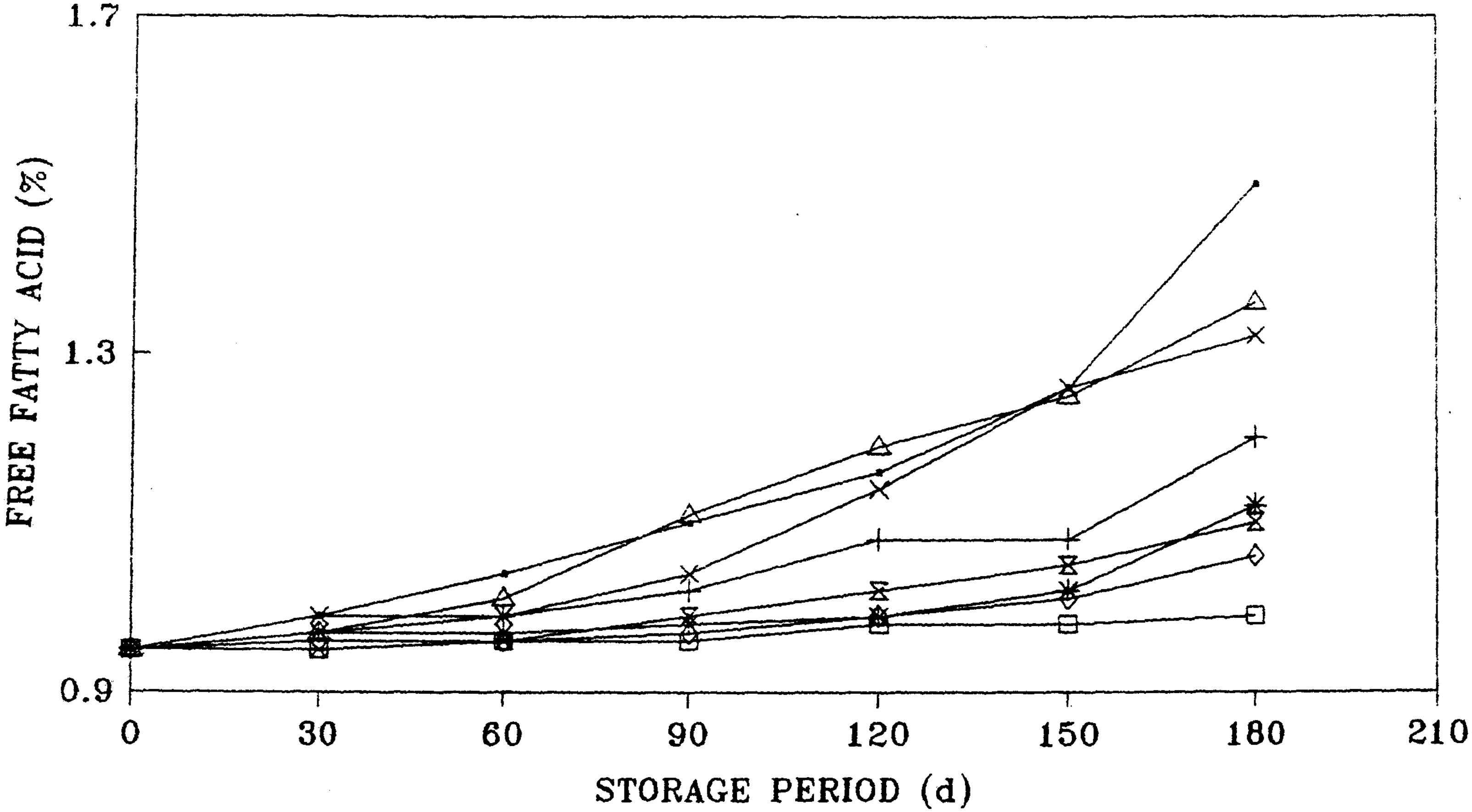

Fig. 19. Effect of packaging and storage on free fatty acid of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

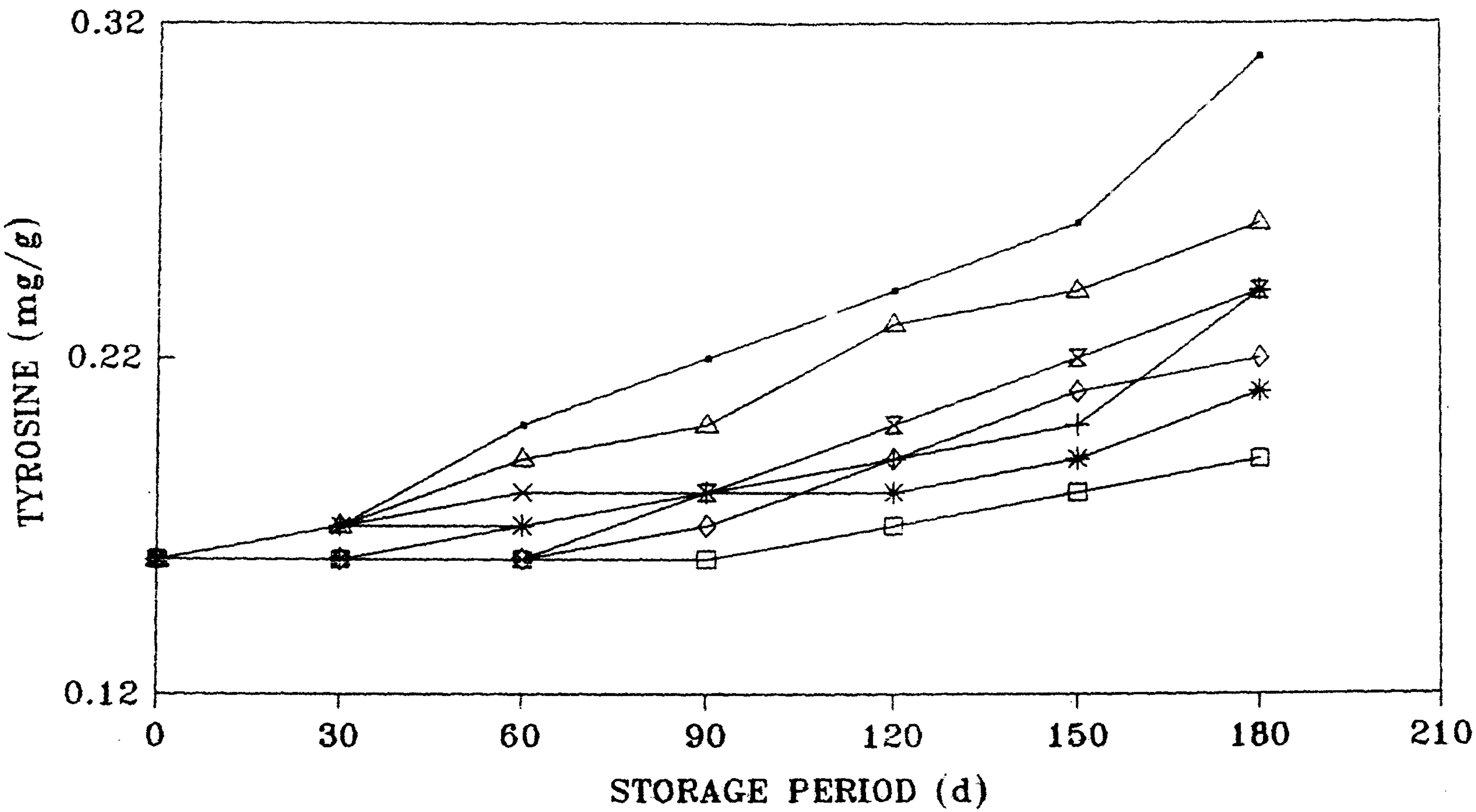

Fig. 20. Effect of packaging and storage on tyrosine of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

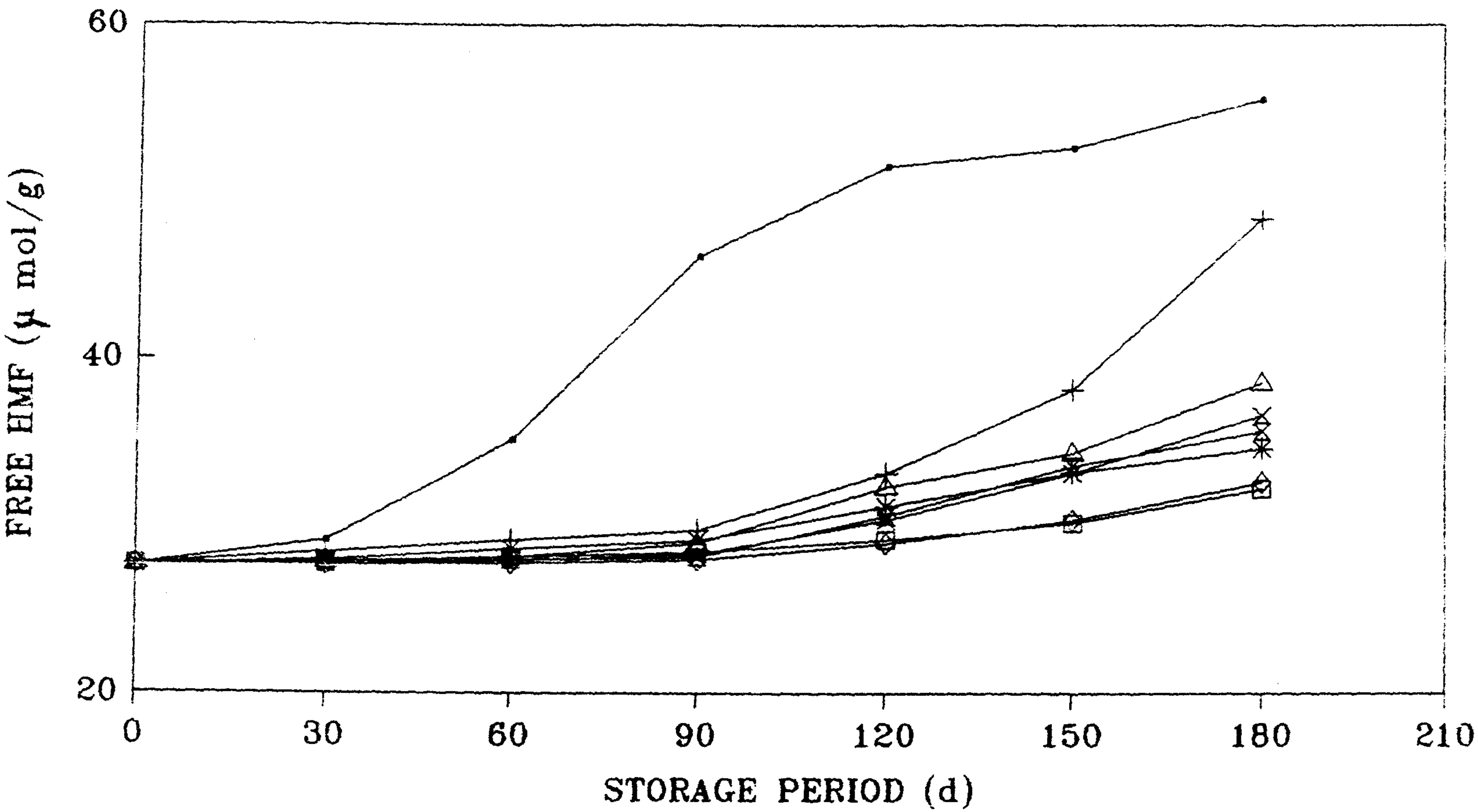

Fig. 21. Effect of packaging and storage on free hydroxymethylfurfural of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

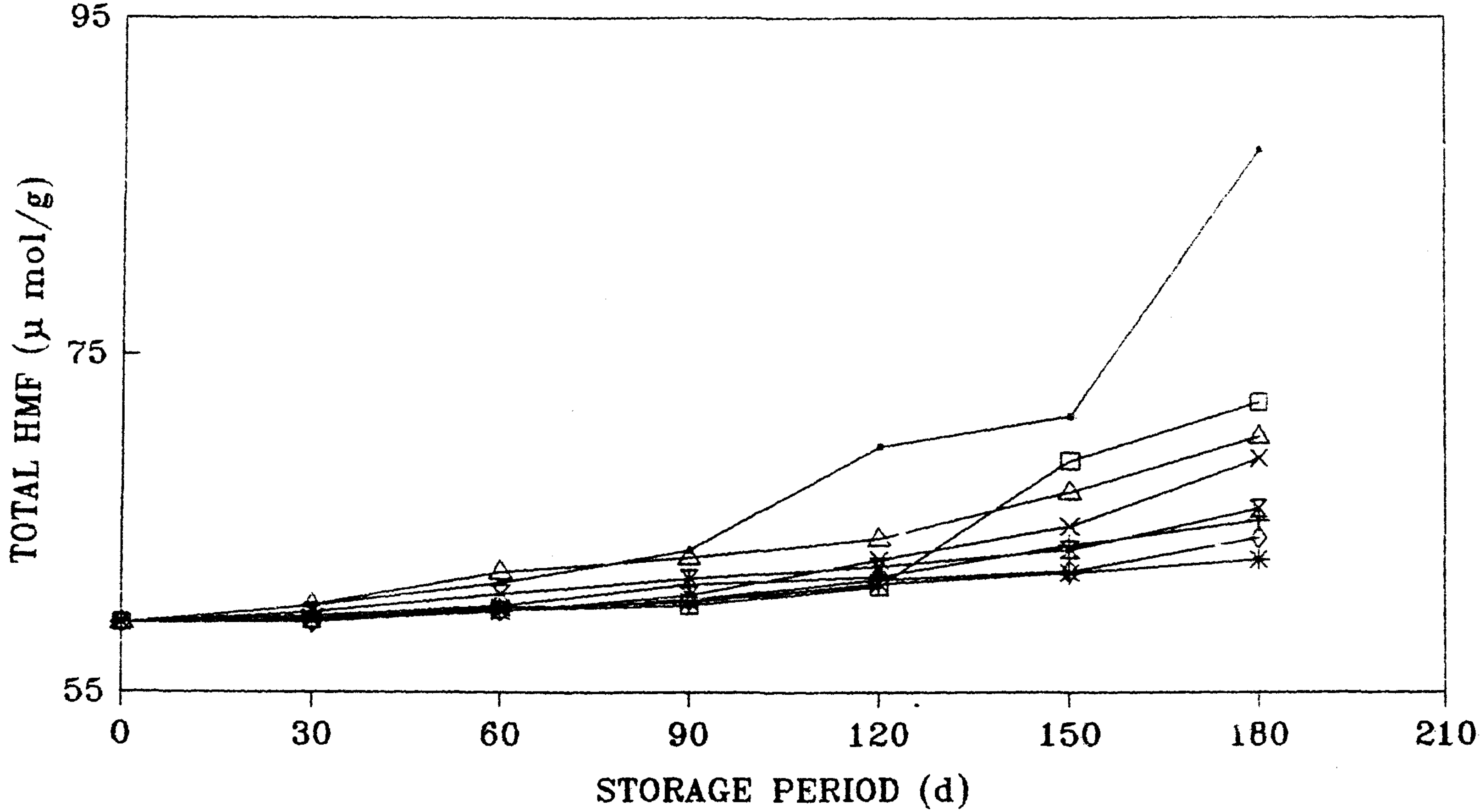

Fig. 22. Effect of packaging and storage on total hydroxymethylfurfural of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

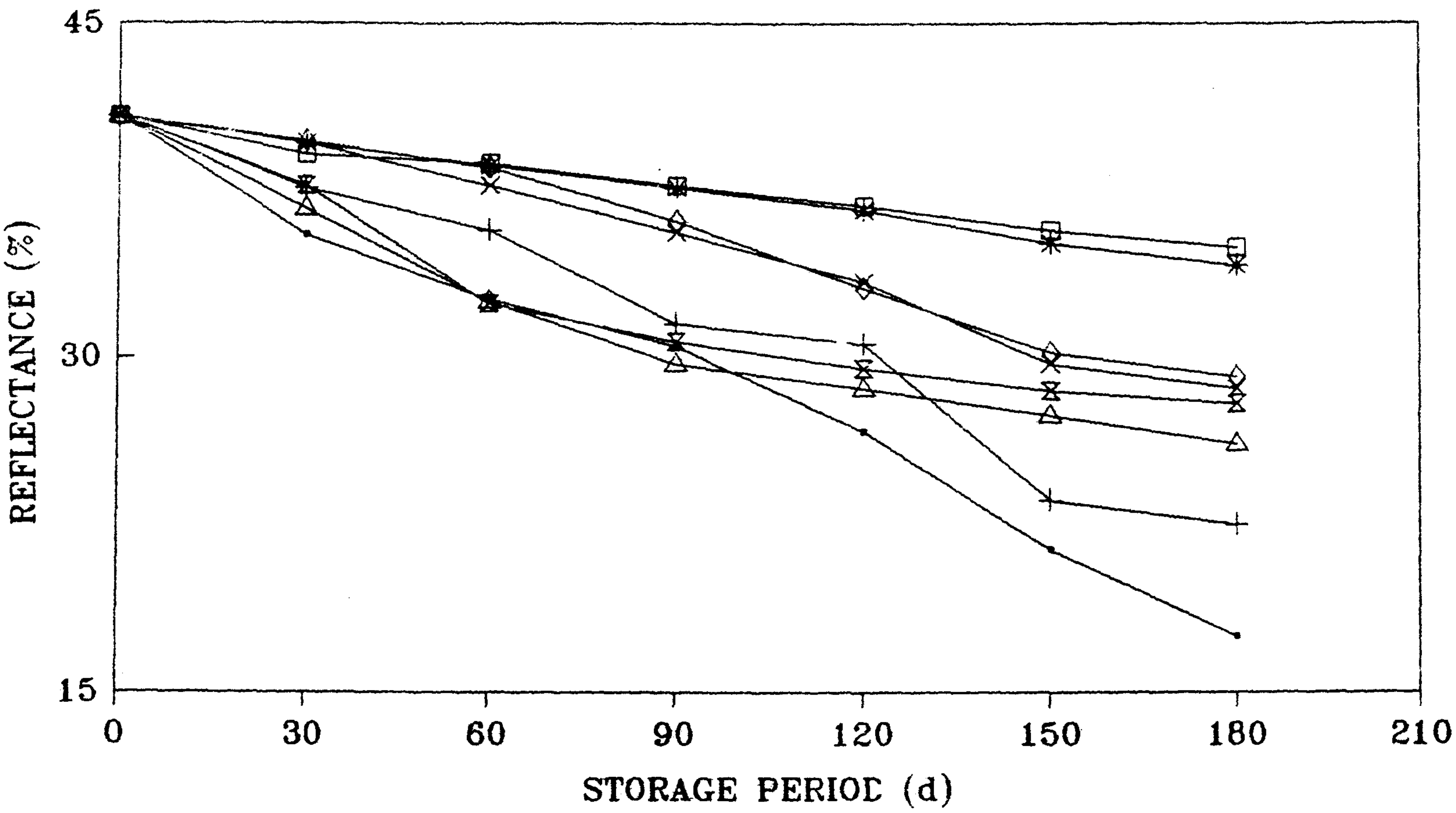

Fig. 23. Effect of packaging and storage on reflectance of dudh churpi

P1A, without packaging and preservative;
P1B, without packaging and with preservative;
P2A, glass container and without preservative;
P2B, glass container and with preservative;
P3A, plastic container and without preservative;
P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative;
P4B, plastic pouch and with preservative;

Table 36. Regression equations for physico-chemical parameters during storage of dudh churpi

Parameter	Packaging material and form*	Regression equation**	Coefficient of correlation (R)
Moisture (M)	P_1A	$M = 15.33+1.81x10^{-2}t-3.00x10^{-6}t^2$	0.99
	P_1B	$M = 15.51-2.73x10^{-3}t+8.90x10^{-5}t^2$	0.98
	P_2A	$M = 15.53+2.97x10^{-4}t+1.70x10^{-5}t^2$	0.99
	P_2B	$M = 15.52+4.52x10^{-4}t+7.00x10^{-6}t^2$	0.98
	P_3A	$M = 15.47+5.20x10^{-3}t-1.00x10^{-6}t^2$	0.98
	P_3B	$M = 15.45+4.26x10^{-3}t-2.00x10^{-6}t^2$	0.94
	P_4A	$M = 15.50+2.53x10^{-3}t+1.30x10^{-5}t^2$	0.99
	P_4B	$M = 15.53-8.30x10^{-4}t+2.80x10^{-5}t^2$	0.99
Free HMF (FHMF)	P_1A	$FHMF = 25.27+0.21t-4.00x10^{-5}t^2$	0.98
	P_1B	$FHMF = 28.06-0.02t+4.53x10^{-4}t^2$	0.99
	P_2A	$FHMF = 27.65-2.94x10^{-3}t+2.07x10^{-4}t^2$	0.99
	P_2B	$FHMF = 27.86-9.90x10^{-3}t+1.82x10^{-4}t^2$	0.99
	P_3A	$FHMF = 27.95-3.15x10^{-2}t+4.40x10^{-4}t^2$	0.95
	P_3B	$FHMF = 27.88-2.11x10^{-2}t+2.58x10^{-4}t^2$	0.99
	P_4A	$FHMF = 27.83-2.17x10^{-2}t+4.50x10^{-4}t^2$	0.99
	P_4B	$FHMF = 27.78-2.23x10^{-2}t+3.77x10^{-4}t^2$	0.99
Total HMF (THMF)	P_1A	$THMF = 61.63-14.83x10^{-2}t+1.52x10^{-3}t^2$	0.95
	P_1B	$THMF = 59.12+9.95x10^{-3}t+1.31x10^{-4}t^2$	0.99
	P_2A	$THMF = 59.05+1.15x10^{-2}t+5.50x10^{-5}t^2$	0.99
	P_2B	$THMF = 59.00+1.32x10^{-2}t+2.90x10^{-5}t^2$	0.98
	P_3A	$THMF = 59.26-1.71x10^{-2}t+3.83x10^{-4}t^2$	0.99
	P_3B	$THMF = 59.05+4.18x10^{-3}t+1.28x10^{-4}t^2$	0.99
	P_4A	$THMF = 59.38+2.00x10^{-2}t+2.09x10^{-4}t^2$	0.99
	P_4B	$THMF = 60.12+9.95x10^{-3}t+1.05x10^{-4}t^2$	0.99

Table 36. Continued

Parameter	Packaging material and form[*]	Regression equation[**]	Coefficient of correlation (R)
Reflectance (Re)	P_1A	$Re = 39.45-5.62x10^{-2}t-3.70x10^{-4}t^2$	0.96
	P_1B	$Re = 40.69-8.48x10^{-2}t-1.10x10^{-4}t^2$	0.99
	P_2A	$Re = 40.73-3.34x10^{-2}t-1.00x10^{-5}t^2$	0.99
	P_2B	$Re = 40.57-3.43x10^{-2}t+1.50x10^{-5}t^2$	0.99
	P_3A	$Re = 41.04-5.15x10^{-2}t-1.10x10^{-4}t^2$	0.99
	P_3B	$Re = 41.15-4.77x10^{-2}t-1.20x10^{-2}t^2$	0.99
	P_4A	$Re = 40.62-1.56x10^{-1}t+4.28x10^{-4}t^2$	0.99
	P_4B	$Re = 41.01-1.55x10^{-1}t+4.62x10^{-4}t^2$	0.99

[*]P_1, without packaging; P_2, glass container; P_3, plastic container; P_4, plastic pouch; A, without preservative; and B, with 0.1% potassium sorbate

[**]Storage period (d)

4.4.2.5. Hydroxymethylfurfural value

Both free and total HMF content of dudh churpi were determined to evalute the progression of Maillard browning during storage of the product. In all the cases, the free and total HMF contents increased with the increase in storage period, but the rate of progression was considerably less when the samples were treated with 0.1% sorbate. The least increase in free (from initial value of 27.69 to 32.23 μmol/g) and total (from initial value of 59.11 to 62.86 μmol/g) HMF content was observed in the samples added with the sorbate and in glass containers (Figs 21 and 22).

4.4.2.6. Reflectance

With the progression of Maillard browning there was a gradual drop in percent reflectance at 450 nm. In concurrence with the observation of browning, the change in reflectance was also minimum (from initial value of 40.80 to 34.90%) in the samples added with 0.1% sorbate and stored in glass containers (Fig. 23).

4.4.2.7. Regression equations

Regression equations for the values of moisture, free and total hydroxymethylfurfural and reflectance are presented in Table 36. The changes in all the physico-chemical parameters fit best to the second degree equations. Howwever, the first degree fits also yielded comparable results. Moisture, free and total HMF and reflectance values can be explained by quadratic regression model of the type $y = A + Bt + Ct^2$ with a correlation coefficient

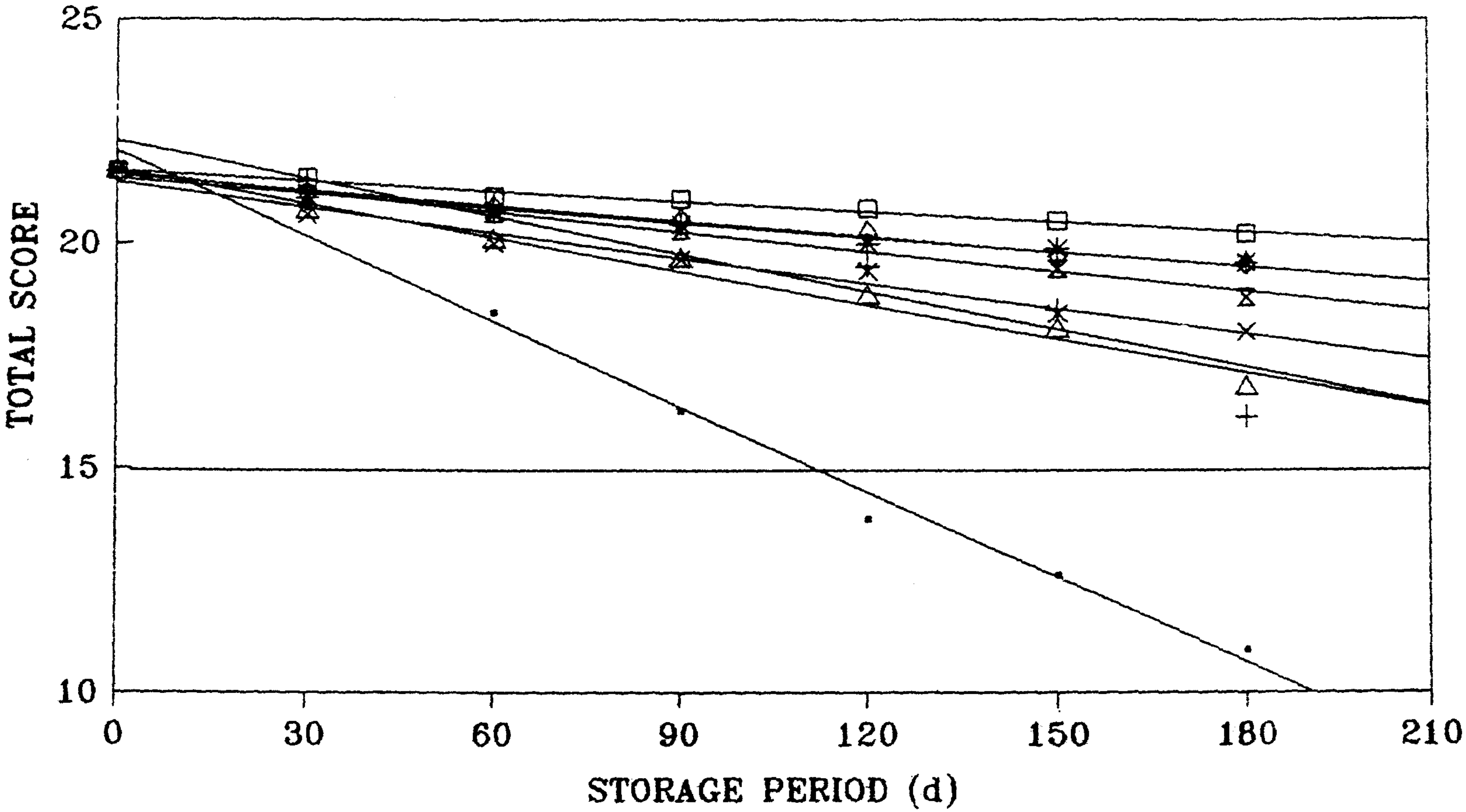

Fig. 24. Effect of packaging and storage on total scores of dudh churpi

P1A, without packaging and preservative; P1B, without packaging and with preservative;
P2A, glass container and without preservative; P2B, glass container and with preservative;
P3A, plastic container and without preservative; P3B, plastic container and with preservative;
P4A, plastic pouch and without preservative; P4B, plastic pouch and with preservative;

of more than 0.96, where y is a physico-chemical parameter, t is the storage period in days and A, B and C are the constants of regression model.

4.4.2.8. Predicted shelf-life of dudh churpi

The shelf-life of the product was assessed from the regression line of the mean overall acceptability scores or total scores on storage period, assuming the total score '15' to be the limit, below which the product was not acceptable. The sensory scores for overall acceptability and the shelf-life of the product are shown in Fig. 24 and Table 37. The figures of these regression equations to the data were tested by calculating % RMS which ranged between 0.286 to 3.357. The low % RMS value shows that the equations fit well to the data. Analysis of variance of mean overall acceptability scores indicated that there was a significant ($P<0.05$) difference due to the use of potassium sorbate in prolonging the shelf-life of dudh churpi. The predicted shelf-life of dudh churpi added with 0.1% sorbate and stored in glass container is 871 days which is significantly ($P<0.01$) higher than the other conditions.

4.5. Water sorption characteristics of dudh churpi

4.5.1. Sorption isotherms of dudh churpi

Moisture sorption isotherms of dudh churpi were determined at 15, 25, 35 and 45°C over an a_w range of 0.11 to 0.97. Adsorption isotherms of dudh churpi are shown in Fig 25. In general, the equilibrium moisture content

Table 37. Shelf-life prediction of dudh churpi packed with different packaging materials and stored at ambient condition

Packaging material and form*	Regression equation**	Coefficient of correlation (R)	%RMS	Predicated shelf-life (d)
P_1A	$y = 22.05 - 6.31 \times 10^{-2}t$	-0.99	2.402	112
P_1B	$y = 22.29 - 2.79 \times 10^{-2}t$	-0.93	3.357	261
P_2A	$y = 21.44 - 1.09 \times 10^{-2}t$	-0.96	0.487	592
P_2B	$y = 21.63 - 0.76 \times 10^{-2}t$	-0.93	0.286	871
P_3A	$y = 21.36 - 1.88 \times 10^{-2}t$	-0.97	0.918	339
P_3B	$y = 21.53 - 1.13 \times 10^{-2}t$	-0.97	0.302	577
P_4A	$y = 21.63 - 2.50 \times 10^{-2}t$	-0.98	1.134	265
P_4B	$y = 21.59 - 1.48 \times 10^{-2}t$	-0.96	0.493	444

*P_1, without packaging; P_2, glass container; P_3, plastic container; P_4, plastic pouch; A, without sorbate; and B, with 0.1% sorbate. **y, overall ecceptability (total score); t, period of storage; Predicted shelf-life was calculated on the basis of minimum acceptability score of 15.

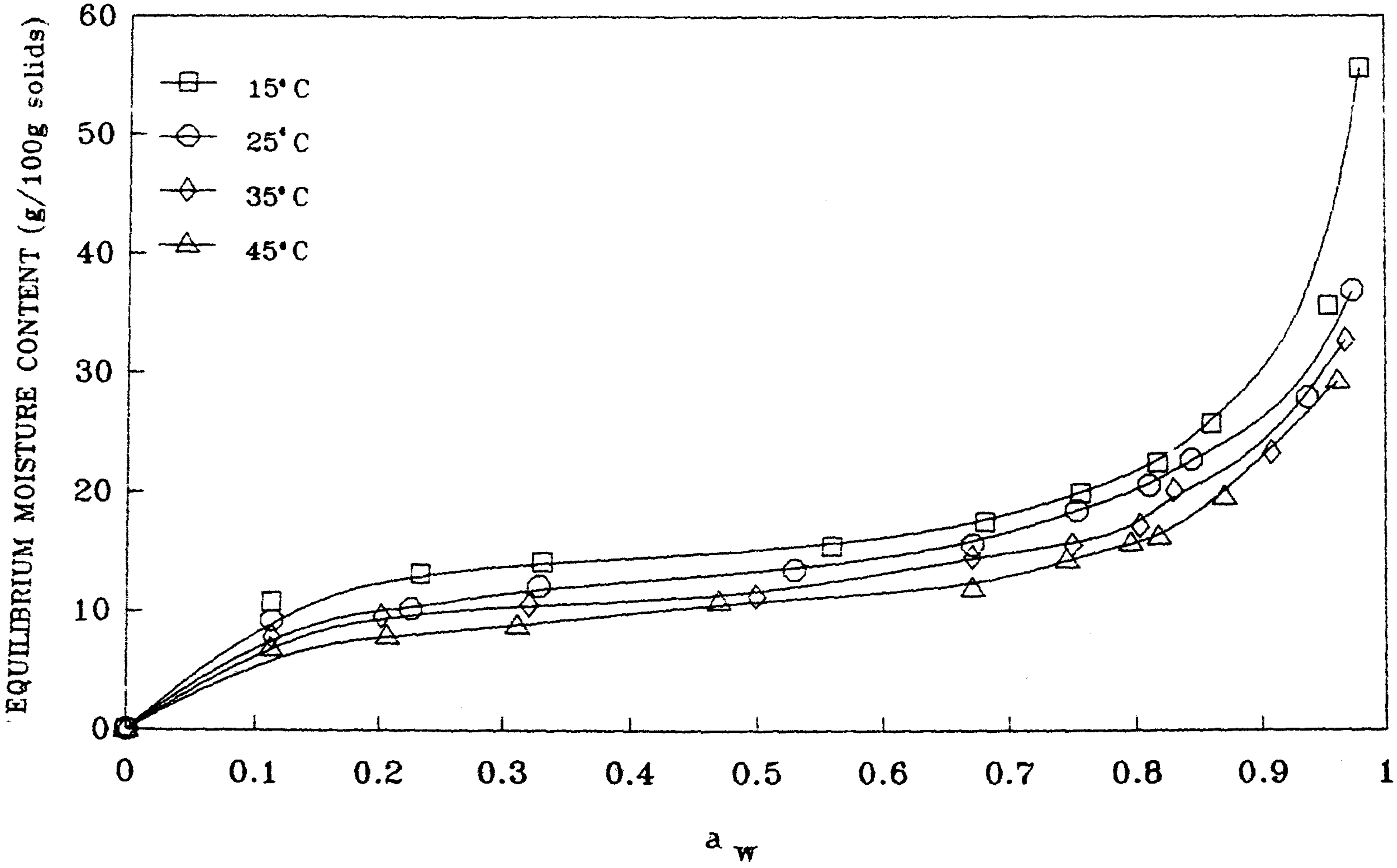

Fig. 25. Moisture sorption isotherms of dudh churpi as influenced by temperature

increased rapidly at low a_w (0-0.15), gradually between 0.15 and 0.78 followed by a steep rise above a_w 0.78. The equilibrium moisture content in dudh churpi increased at 0.97 a_w during adsorption.

4.5.2. Equations describing isotherms of dudh churpi

Of the nine equations fitted to the sorption data in the range of 0.1125-0.9790. Bradely, Henderson, Iglesias and Chirife, Khun and Mizrahi equations exhibited high % RMS values. However, these equations seemed to fit well in two ranges, sometimes three ranges with % RMS values ranging from 2.0934-9.4112. The corresponding a_w ranges and constants are given in Appendix 1.

In dudh churpi, four equations gave good fit over the full range of isotherms. They are GAB, modified Mizrahi, Caurie and Oswin. However, Cauries equation showed fairly low RMS values when fitted in full ranges of adsorption data of dudh churpi. Cauries equation was well studied to describe the adsorption of dudh churpi. Monolayer values were determined using these equations. The a_w ranges, equation constants and RMS values of GAB, modified Mizrahi, Caurie and Oswin's equations at 15, 25, 35 and 45°C are shown in the Table 38.

4.5.3. Effect of temperature on isotherms of dudh churpi

Increase in temperature tends to shift the isotherms to right hand (Fig. 25). As the temperature increased, a_w at a given moisture content of dudh churpi increased, but above a_w 0.93, this effect diminished. In other words, as the temperature increased, the equilibrium moisture content of dudh churpi at a

Table 38. Sorption ranges, constants and % root mean square (RMS) values of dudh churpi for selected equations at different temperatures

Equation	Temperature (°C)	a_w	Constants* a	b	c	% RMS
GAB	15	0.2325-0.9530	7.3202	-11.5491	0.8191	4.5493
	25	0.1125-0.9360	8.1048	-44.3188	0.0289	4.9136
	35	0.2013-0.9070	6.4139	-21.5861	0.0561	4.2911
	45	0.1115-0.8695	6.5245	-112.6264	1.4857	5.3148
Modified Mizrahi	15	0.1125-0.9790	-10.0090	-0.4720	9.6321	5.0465
	25	0.1125-0.9730	-7.8351	-3.2597	10.3342	8.5016
	35	0.1125-0.9670	-7.1273	-2.2615	8.6097	7.3936
	45	0.1115-0.9610	-5.8734	-3.2226	8.3639	4.9154
Caurie	15	0.1125-0.9530	1.3599	11.9727	——	6.9631
	25	0.1125-0.9360	1.3153	10.7617	——	5.0246
	35	0.1125-0.9070	1.2345	10.1683	——	6.1110
	45	0.1115-0.8695	1.1839	9.3107	——	5.0554
Oswin	15	0.1125-0.9530	16.2570	0.2272	——	6.9631
	25	0.1125-0.9730	14.1672	0.2528	——	5.1679
	35	0.1125-0.9670	12.6706	0.2570	——	6.6762
	45	0.1115-0.9610	11.1141	0.2725	——	6.2143

*a, b and c correspond to constants M_m, C and K respectively in GAB equation; a and b in modified Mizrahi equation; a and b represent C and M_m respectively in Caurie's equation.

given a_w decreased.

The effect of temperature was evaluated by Caurie's equation whose constants are given in Table 39. The monolayer value and density of sorbed water decreased with the increase in temperature. Monolayer value decreased from 11.9727 to 9.3107 % with the increase in temperature of sorption from 15 to 45°C (Table 38).

A relationship of the Caurie's constants with temperature was established. The corresponding equations are shown in Table 40.

4.5.4. Properties of bound water and surface area of the adsorbent

Several aspects of bound water in dudh churpi are presented in Table 41. The surface area on which adsorption took place was determined by the formula given by Caurie (1981):

$$A = \frac{54.45}{S}$$

where, A = surface area, m^2/g and

S = slope of Caurie's plot

Number of adsorbed monolayers was calculated by the formula (Caurie 1981):

$$S = 2/N$$

where, S = slope of Caurie's plot and

N = number of adsorbed monolayers

Monolayer value and density of bound water are indicated by M_m and C values respectively of Caurie's equation. Percent bound or non-freezing water is the product of monolayer value (M_m) and number of adsorbed

Table 39. Effect of temperature on isotherm parameters of dudh churpi

Equation	Temperature (°K)	Isotherm parameters[a]		% RMS
		M_m(T)	C(T)	
Caurie	288	11.9022	1.3702	5.0607
	298	10.9145	1.3044	5.1510
	308	10.0652	1.2457	6.1282
	318	9.3294	1.1931	5.2135

[a]M_m(T), monolayer moisture content; C(T), density of the sorbed water

Table 40. List of equations showing relationship of isotherm parameters with temperature of adsorption of dudh churpi

Isotherm equation	Relationship of isotherm parameters with temperature[a]
Caurie	$Mm(T) = 0.9003e^{6181.724/RT}$
	$C(T) = 0.3161e^{3511.6503/RT}$

[a]$M_m(T)$, monolayer moisture content (g/100 g solids) at a specified temperature;

C(T), density of the sorbed water (g/ml) at a specified temperature;

T, temperature(°K); R, universal gas constant (8.31432 Joules/°K/mole)

Table 41. Properties of bound water and surface area of the adsorbent for dudh churpi

Temperature (°C)	Adsorbed monolayers (N)	monolayer moisture (g / 100 g solids)	Density of sorbed water (g/ml)	Bound or non-freezing water (g / 100 g solids)	Surface area of adsorption (m^2/g)
15	8.8039	11.9727	1.3599	105.4064	239.6862
25	8.1820	10.7617	1.3153	88.0523	239.9067
35	8.2365	10.1683	1.2345	83.7512	224.2387
45	7.8644	9.3107	1.1839	73.2230	214.1056

monolayers (N).

With the increase in temperature the number of adsorbed monolayers reduced from 8.8039 to 7.8644 and the monolayer moisture content dcreased from 11.9727 to 9.3107 g/100 g solids. Density of sorbed water and bound water content also declined with the increase in temperature. Although the surface area of adsorbent reduced from 239.6862 at 15°C to 214.1056 m^2/g at 45°C, there was no significant reduction in surface area of adsorbent between 15 and 25°C (Table 41).

4.6. Consumer response to laboratory-made dudh churpi

The consumers' preference trial with the best quality market samples of dudh churpi from Bhutan and those prepared in laboratory indicates their equal acceptance (Table 42).

Out of 127 male and equal number of female respondents from different families, 77 were below the age of 16, 98 within the age group of 16-25 years, 73 within 25-50 years and only 6 were over 50 years old. The respondents were broadly divided into three income groups: 41% below the income level of Rs 2500, 38% within Rs 2501-5000 and 21% over Rs 5000 per month.

All the respondents expressed their frequency of eating dudh churpi either as 'several times a week' or 'several times a month'. None of the respondents mentioned any specific time of eating this product.

Out of total 254 respondents, 105 preferred market samples to laboratory-made ones and 33 accepted both the samples equally. Eighty-five percent and 15% indicated their reasons for preference of market smaples over laboratory-made product as better colour and overall sensory quality,

Table 42. Consumers' response to best available market (Bhutan) and laboratory-made dudh churpi

	No. of consumers*	
Overall response	Market	Laboratory-made
Preferred extremely	20 (7.87)	23 (9.05)
Preferred very much	25 (9.84)	21 (8.27)
Preferred moderately	29 (11.42)	34 (12.20)
Preferred slightly	31 (12.20)	38 (14.96)
No preference	33 (12.99)	

*Percent respondents are indicated in parentheses.

respectively. Out of 116 respondents who preferred laboratory-made samples, 43% indicated better flavour, 27% better texture and 30% both flavour and texture as their reasons for preference.

4.7. Cost of production of dudh churpi

The cost model described in Table 43 is developed on the basis of actual trials conducted under optimized process conditions.

Estimated cost of production of dudh churpi was worked out to be Rs 116.82 per kg i.e. Rs 23.36 per 200 g glass bottle (Rs 182.56 - 56.40 - 9.34) (Table 43 and Annexure - IV)

The business of dudh churpi production is quite remunerative. It can be observed that conversion of 108 l of cow milk per day into dudh churpi with a small amount of by products like ghee and whey, resulting out of standardization and souring of milk, will earn a net profit of about Rs 8048 per month with a total capital investment of Rs 46,300 and the annual operating cost of Rs 3,03,085.

Table 43. Statement of cost for the production of dudh churpi

Sl. No.	Item of cost	Output: 1660.2 kg yield of dudh churpi		
		Annexure	Amount (Rs)	Per Uni (Rs)
1.	Input			
1.1.	Raw materials	I	1,65,462	99.66
1.2.	Labour, utilities, house rent, packaging and others	II	72,342	43.57
1.3.	Depreciation on fixed assets and interest on capital investment	III	65,281	39.33
	Cost of production		3,03,085	182.56
2.	Output	IV	3,99,669	240.74
	Profit (2 - 1)		96,584	58.18

Annexure-I

Raw materials

Sl No.	Particulars	Quantity	Rate (Rs)	Amount (Rs)	Per unit (Rs)
1.	Cow milk				
	(3.5% Fat and 8.7% SNF)	39,420 l	4/l	1,57,680	94.98
2.	Citric acid	84 kg	70/kg	5,880	3.54
3.	Markin cloth	120 m	10/m	1,200	0.72
4.	Sugar	58.5 kg	12/kg	702	0.42
		Total:		1,65,462	99.66

Labour and others

Sl No.	Particulars	Quantity	Rate (Rs)	Amount (Rs)	Per unit (Rs)
1.	Labour charges				
	Unskilled	1	20/day	7,300	4.40
	Skilled	1	30/day	10,950	6.59
2.	Utilities				
	Steam	9,125 kg	0.75/kg	6,844	4.12
	Water	21,900 l	1/1000 l	219	0.13
	Electricity	1,825 kW	1/kW	1,825	1.10
3.	House rent		750/month	9,000	5.42
4.	Packaging charges	8,301 pcs	4/200 g bottle	33,204	20.0
5.	Quality control expenses			2,400	1.45
6.	Miscellaneous expenses			600	0.36
		Total:		72,342	43.57

Depreciation of fixed assets and interest on capital investment

Sl No.	Particulars	Quantity	Rate (Rs)	Amount (Rs)	Per unit (Rs)
1.	Depreciation on fixed assets				
	@ 10% per annum	46,300		4,630	2.79
2.	Interest on fixed capital				
	investment @ 18% per annum	46,300		8,334	5.02
3.	Interest on working capital				
	investment @ 22% per annum	2,37,804		52,317	31.51
		Total:		65,281	39.32

Annexure - IV

Output

Sl No.	Particulars	Quantity	Rate (Rs)	Amount (Rs)	Per unit (Rs)
1.	Yield of dudh churpi	1,660.2 kg (4.21 kg per 100 kg cow milk)	175/kg	2,90,535	175.00
2.	Surplus fat	936.225 kg (2.7 kg per day) converted into ghee (95% recovery)	100/kg	93,622	56.40
3.	Whey	2,500 l	0.50/l	15,512	9.34
		Total:		3,99,669	240.74

Detailed list of fixed assets

Sl No.	Particulars	Quantity (Rs)	Rate / unit	Amount
1.	Aluminium milk can	6 pcs	800 / can	4,800
2.	Cream separator	1 pc	3,000 each	3,000
3.	Mini boiler 50 kg / h water evaporation capacity	1 pc	20,000 each	20,000
4.	Heating vessel, 250 l capacity	1 pc	5,000 each	5,000
5.	Drier	1 pc	10,000 each	10,000
6.	Weighing balance	1 pc	1,500 each	1,500
7.	Laboratory equipment			2,000
		Total:		46,300

5. DISCUSSION

5.1. Survey on tradition of dudh churpi

The organized milk sectors and private vendors of Bhutan, Sikkim and Darjeeling procure milk from different villages of these areas where motorable road facility exists. But, thousands of milk producers of remote villages still can not sale their surplus milk to these agencies due to topographical constraints. Unprocessed milk, where clean milk production is not practiced, develops acidity within 4-5 h. Hence to preserve milk solids, the milk producers of those places convert their surplus milk into butter, churpi and dudh churpi. Churpi and dudh churpi are believed to be highly nutritious, energy giving and a shelf stable product (SSP). They can be shelved upto one year and, therefore, provide a vehicle for preserving the valuable nutrients in milk and making those nutrients available throughout the year. During mastication, they help in greater amylase secretion which, in turn, provides higher activation energy duriong uphill trekking.

5.2. Analyses of market samples of dudh churpi

5.2.1. Chemical, sensory and instrumental analyses

Wide variation in the contents of moisture, fat and protein in the market samples of dudh churpi from different sources was likely due to the difference in type of milk, method of separation, heat treatment of the curd and treatment with concentrated sugar solution of milk. Lactose and glucose-galactose content of the samples of Bhutan and Sikkim indicated little or no evidence of lactose hydrolysis. Considerable hydrolysis of milk sugar in the samples of Darjeeling might apparently be due to the lack of heat treatment of milk and/or green curd and higher moisture content at the onset of drying An appreciable amount of lactose was found in the market samples of chhana (Nasir *et al.* 1987). Free fat content ranged between 23 and 25% of total fat. High free fat content in the samples of dudh churpi may be explained as the combined action of scraping and agitation during cooking of green curd and treatment of partially dried product (prechurpi) with concentrated sugar solution. This causes rupture of fat globule membrane resulting in the release of higher amount of free fat. Coagulation of protein in the fat globule membrane also contributes to freeing of fat (Ranganadhan and Rajorhia 1989).

Water-dispersible protein (WDP) of market samples of dudh churpi varied from 6.5 to 13.5% of the total protein content. The higher WDP in the samples of Darjeeling indicated that a smaller portion of the total protein was transferred to the solid network, and that resulted in lower cohesive force and cosequently less hard dudh churpi. In the market samples of churpi, the WDP content was reported to be 5.7-12.3% of total protein (Pal 1994).

High titratable acidity and low pH in the samples of Darjeeling could be associated with high moisture content at the onset of drying of the product which might have initiated greater microbial metabolism.

Among the milk and milk products, cheddar cheese and churpi which give 1.7 and 1.5 MJ/100 g energy respectively (De 1980; Pal 1994) are comparable to the energy value of dudh churpi (1.6 MJ/100 g).

Compared to other chhana-based milk products (Sen and Rajorhia 1989), the free fatty acid (FFA) of dudh churpi was fairly high. The reason for higher release of FFA could be due to the hydrolysis of fat by exocellular lipases of pseudomonads which are not inactivated even after ultra-high temperature (UHT) processing (Renner 1979).

Prolonged drying at elevated temperature (>30°C) and in open air could be responsible for higher 2-thiobarbituric acid (TBA) value of market dudh churpi (Wadsworth and Bassette 1985). Moreover, milk contains many minor polyunsaturated fatty acids, and the autooxidation of dairy products can lead to a multitude of saturated and unsaturated aldehydes resulting in higher TBA values (Kurtz 1974).

Tyrosine value in the samples of Bhutan and Sikkim was much less than that of fermented dairy products (Vema and Anand 1987), which indicated little or no evidence of proteolysis in dudh churpi. Severe heat treatment during preparation of dudh churpi in Sikkim and Bhutan might cause the destruction of milk proteases resulting in a lower tyrosine value. Probably due to lack of heat treatment of milk/green curd the tyrosine value in the samples of Darjeeling was fairly high.

Heat processing of milk and other food products leads to complex changes and interactions among the constituents. During a study of effect of heat on milk at elevated temperature, the observation was made that the product, after heat sterilization, developed a capacity for reacting with p-dimethylaminobenzaldehyde (p-DMAB). By measuring the p-DMAB reactivity, the extent of heat treatment to milk and milk products could be found out (Hansen 1967). It was evident that the samples of dudh churpi of Darjeeling had less p-DMAB reactivity and were much less heat treated than the samples of two other sources.

5-Hydroxymethylfurfural (HMF) is one of the intermediate products of Maillard reaction and its formation depends primarily on heating temperatures, moisture content and also storage conditions. Both free and total HMF content in the samples of three different areas were exceptionally high than any other dairy products (Caric *et al.* 1984). The samples of Sikkim with maximum HMF content resulted in minimum reflectance, and those of Darjeeling with least HMF content showed maximum reflectance. Higher reflectance could be explained by the formation of melanoidin. During Maillard reaction HMF or furfural is produced under acidic conditions, and reductones and dehydroreductones are produced under mild acidic to basic conditions. These can undergo Strecker degradation, and at high temperatures fragmentation products from the Amadori product are produced. Polymerization of the products from the second phase yields brown melanoidin pigments in the third and final phase of the Maillard reaction (Labuza and Saltmarch 1981). These brown pigments interferes the passage of light through the samples. Higher HMF value could be attributed due to higher heat treatment such as open pan heating with constant stirring which together reduced the inhibitory effect of free sulphydryls on browning, as incorporation of oxygen during stirring oxidizes free sulphydryls (Nagendra *et al.* 1991). This can be further attributed to higher heat treatment in pan because the heat source is limited to bottom of the pan and provides greater activation energy for HMF accumulation (Golubonic *et al.* 1983). Moreover, direct contact of super-saturated solution of lactose with hot surface of pan could enhance lactose caramelization resulting in the formation of HMF (De 1980).

5.2.2. Relationship between sensory attributes and intrinsic parameters

A high negative correlation (P<0.001) of flavour with lactic acid is presumably associated with the growth of microorganisms by utilizing lactose (Mandokhot and Garg 1985). Lactose degradation is further evident from high titratable acidity/low pH values of the samples of Darjeeling. A high level of lactic acid gives rise to sour smell and taste which are not desired in dudh churpi. Significantly adverse effect of FFA and TBA on the flavour of dudh churpi could be associated with lipolysis and with the autooxidative products of unsaturated fatty acids, mainly oleic, linoleic and linolenic together with phospholipids (Kinsella *et al.* 1967). Browning is not usually desirable in food products because of the production of reducing substances, fluorescent substances and disagreeable flavour materials during Maillard reaction (Nickerson 1974). But these substances seem to influence the characteristic flavour profile of dudh churpi, and consequent to this postulation a high positive correlation ($P<0.001$) of free and total HMF with flavour was observed.

A higher heat treatment provides greater activation energy to form higher amount of free and potential HMF (Berk 1976) and increases the protein-protein interactions (Saio *et al.* 1968; Catsimpoolas *et al.* 1969,1970) leading to higher compactness. This justifies the positive correlation ($P<0.001$) of p-DMAB reactivity and free and total HMF values with body and texture scores of dudh churpi. A high tyrosine content indicates extensive protein hydrolysis which is detrimental to the characteristic body and texture profile of dudh churpi. Extensive protein hydrolysis in the samples of churpi of Darjeeling resulted in brittle and crumbly body (Pal 1994). Thus, a high negative correlation ($P<0.001$) was observed with body and texture scores and tyrosine content of dudh churpi.

5.2.3. Relationship between chemical composition and Instron parameters

A high positive correlation ($P<0.01$) of Instron hardness with total solids of dudh churpi and a negative correlation ($P<0.01$) with WDP may be explained in the light of moisture and protein contents of the product. Increase in total solids content decreases free moisture and increases the protein proportion of the product (Patel *et al.* 1993) resulting in greater hardness. Higher WDP means that only a smaller portion of the total protein was tranferred to the solid network resulting in lower hardness. Inelastic stretching of the protein molecules caused by the combined effect of coulombic repulsion and thermal vibration increases the entropy of a system (Jolly 1965). The possibility of such an effect cannot be ignored in dudh churpi, since it undergoes severe heat treatment in the three different stages. A similar observation was made in churpi (Pal 1994).

Contrary to hardness, cohesiveness in khoa decreased substantially with the increase in its total solids content. This might be due to the decreased free moisture content in the product. The increase in total solids was accompanied by a decrease in cohesiveness of khoa (Rajorhia *et al.* 1991; Patel*et al* 1993). Total fat, free fat, WDP and total sugar presumably have a declining effect in the interparticle binding causing a less cohesive dudh churpi.

Since gumminess is a product of hardness and cohesiveness, it showed a positive correlation with total solids and a negative correlation with WDP content.

The significant impact of compositional variables on Instron texture parameters provides ample information in determining textural chracteristics of the product. No literature is available on such inter-relationships of dudh churpi. However, the impact of compositional variables on Instron textural parameters is found in chhana (Desai 1988), Khoa (Gupta *et al.* 1990) and churpi (Pal 1994).

5.2.4. Relationship between sensory textural descriptors and Instron texture profile parameters

A high positive correlation ($P<0.01$) was found between Instron hardness and sensory firmness of dudh churpi. Similar correlations were observed in cottage cheese, chhana, paneer, khoa and churpi (Parry and Carroad 1980; Desai 1988; Patil *et al.* 1990; Pal 1994).

Lack of appreciable correlation between Instron cohesiveness and sensory crumbliness indicates that organoleptically perceived crumbliness of dudh churpi may not necessarily be reflected in instrumental cohesiveness as was found in khoa (Patil *et al.* 1990).

Springiness of dudh churpi in combination with hardness predicted better firmness ($P<0.001$) than what it could predict alone. A similar observation was made in khoa and churpi (Patil *et al.* 1990; Pal 1994). Thus, dudh churpi with greater hardness tended to be more springy.

Instron chewiness was significantly correlated ($P<0.001$) with sensory chewiness of dudh chrupi. The corresponding regression equation exhibited only 25% variation in sensory chewiness as explained by Instron chewiness. The poor influence of instrumental chewiness on sensory chewiness may be explained in the light of the followiing phenomenon. Chewiness measured by Instron is taken to represent the sensory chewiness at the bulk level, i.e. considering the whole mass or piece of the product taken for a bite, as in the case of pop corn, unlike in khoa, chhana and paneer, which essentially being granular in nature, exibit chewiness more at the particle level than at the bulk level, i.e. when jaws crushing the piece or bulk come close to each other so that individual grains are crushed. Although the chewiness of individual granules may centribute some of the chewiness of the bulk, it is mainly the hardness, cohesiveness and springiness of these granules that should determine sensorily perceived chewiness (Patil *et al.* 1990). Hence, the Instron chewiness need not necessarily reflect the sensory chewiness of structurally particulate products such as dudh churpi.

As observed in the present study, it is relatively easy to find definite relationship between instrumental and sensory data on certain individual attributes of food texture rather than having a decisive picture of a product texture from its instrumental profile.

5.3. Optimization of process parameters in the manufacturing dudh churpi

5.3.1. Milk used in cooking prechurpi

5.3.1.1. Fat level

During the process of cooking prechurpi, milk flows to prechurpi through a semi-hard coating on its surface. Since it is difficult to obtain a perfect semi-permeable membrane in food systems, there is always some solid diffusion into the food (Rahman 1992). Accordingly the percent total fat, free fat, FFA and TBA values of dudh churpi increased with the increase in fat level in milk used for cooking. Rancid flavour in dudh churpi cooked in milk of 2.0 and 3.0% fat could presumably be due to the higher amount of carbonyls (Day *et al.* 1963). A higher TBA value further justifies this statement (Sidewell *et al.* 1955). Flat flavour in dudh churpi when cooked in skim milk (0.1%) fat is probably due to less amount of fat in the product, since the agreeable flavour of rich milk and of other dairy products is largely due to milk fat (Eckles *et al.* 1973).

Samples of dudh churpi cooked in skim milk exhibited greater Instron values compared to the samples cooked in milk of other fat levels. Lower fat and higher protein content in the samples of dudh churpi when cooked in skim milk exhibited greater aggregation of protein molecules which gave rise to higher instrumental values.

Flavour attribute of dudh churpi, cooked in skim milk, scored less due to less amount of fat present in dudh churpi. Dudh churpi cooked in milk of 2.0 and 3.0% fat also had a lower flavour score due to the association of higher FFA and TBA values. Samples of dudh churpi, cooked in milk of 1.0% fat showed greater potentiality with respect to all the sensory attributes and chemical data. Sensory, chemical and instrumental data of the samples of dudh churpi, cooked in milk of 1.0% fat, closely resembled the data of the best available market churpi of Bhutan. Hence, 1.0% fat was condidered the optimum fat level in milk for cooking prechurpi.

5.3.1.2. Sugar concentration

Higher sensory scores and instrumental values in the samples of dudh churpi, cooked in milk of 1.0% fat and 2.0% sugar, could be explained by maximum solid diffusion during cooking of prechurpi. Lower ($P<0.05$) sensory scores and the instrumental values except cohesiveness, springiness and gumminess in the samples of dudh churpi, cooked in milk of 1.0% fat and 1.0% sugar compared to the samples cooked in milk of 1.0% fat and 2.0% sugar, could be explained by the quicker approach towards concentration equilibrium because of higher concentration of sugar in milk and less water activity gradient thereof (Chaudhari *et al.* 1993). However further increase of sugar concentration in cooking medium (i.e. 3% sugar) lead to deposition of solids on prechurpi surface leading to lower rates of diffusion and deterioration of the quality.

Crystallization of sugar on the surface of the product increases with the increase in sugar level in milk. Direct contact of super-saturated solution with hot surface of pan could enhance lactose caramelization resulting in the formation of higher HMF (De 1980). Higher HMF values in the samples of dudh churpi, cooked in milk of 3.0% sugar, resulted in less ($P<0.05$) colour and appearance score compared to the samples, cooked in milk of less sugar content.

Thus, cow milk of 1.0% fat and 2.0% sugar was found optimum for cooking prechurpi.

5.3.1.3. Total solids content

Increase in sensory scores with the increase in total solids content in milk, used for cooking prechurpi, could be associated with increased concentration gradient. This can further be clarified that osmotic pressure of a solution is directly proportional to its concentration at constant temperature (Palit 1962).

There was no difference ($P<0.05$) in body and texture scores of the samples of dudh churpi, cooked in milk of 23.40 and 29.25% total solids content. Since the instrumental parameters are solely related with the rheology of a product, there was no difference ($P<0.05$) in instrumental values of the samples of dudh churpi, cooked in the milk of 23.40 and 29.25% total solids content.

Hence, cow milk of 1.0% fat, 2.0% sugar and 29.25% total solids content was found optimum for cooking prechurpi.

5.3.2. Time of cooking prechurpi

In general, the amount of diffused solids from milk increases with the increase in cooking time of prechurpi, but the rate of diffusion gradually decreases (Chaudhari *et al.* 1993). Indifference ($P<0.05$) in flavour and body and texture scores in the samples of dudh churpi cooked in milk for 15 and 20 min justifies this statement. Colour and appearance score in the samples of dudh churpi, cooked in milk for 15, min was significantly ($P<0.05$) higher than the samples cooked in milk for 20 min. This could be attributed by enhanced Maillard reaction and formation of larger amount of melanoidin.

Lower ($P<0.05$) cohesiveness, gumminess and chewiness in the samples of dudh churpi cooked in milk for 20 min than the samples cooked in milk for 15 min could be attributed due to more concentration of sugar in the samples and correspondingly less percent protein.

Hence, milk of 1.0% fat, 2.0% sugar and 29.25% total solids and 15 min cooking time were found optimum for cooking prechurpi.

5.3.3. Moisture level

Prechurpi of 40 and 35% moisture levels, cooked in milk of 1.0% fat, 2.0% sugar and 29.25% total solids for 15 min and dried at four different temperature conditions had significantly ($P<0.05$) lower scores with respect to all the sansory attributes compared to the prechurpi of 30 and 25% moisture levels but cooked and dried under identical conditions. This could be attributed to low concentration of osmotic solution of the samples, since both equilibrium and adsorption rate increase with the increase in osmotic syrup concentration (Rahman 1992). Poor sensory scores ($P<0.05$) in the samples of dudh churpi, cooked at 25% moisture level than the samples, cooked at 30% moisture level could be explained by the loss of membrane integrity or change in the pore size due to prolonged heating (Rahman 1992).

Thus, 30% moisture level in prechurpi was found optimum for cooking in milk of 1.0% fat, 2,0% sugar and 29.25% total solids content.

5.3.4. Drying behaviour of cooked prechurpi

Higher rate of drying at the onset of the drying process under all temperature conditions can be attributed to the higher moisture potential available for removal. The rate of drying decreased as the replenishment of water from interior to the surface of prechurpi could not cope up with the fast removal of moisture from the surface. An increase in drying temperature reduced the drying time because it increased the rate of drying.

Since there was no significant ($P<0.01$) difference in Instron parameters of the samples of dudh churpi under each individual temperature conditions, the size of dudh churpi had no effect on its body and textural characteristics.

The samples of dudh churpi exhibited no significant ($P<0.01$) differnce with respect to all the Instron parameters when dried traditionally and in a drying chamber at 35°C . The data on Instron parameters also resemble closely with the best available market samples of Bhutan.

Hence drying of dudh churpi in a drying chamber at 35°C was found optimum and economical, since it saves 50% production time compared to traditional drying process.

No literature is available on drying characteristics of dudh churpi. Pal (1994) presented drying data by Page's model and reported that the size of churpi had no effect on its body and textural characteristics. Ajibola *et al.* (1988) adequately expressed drying data by Page's model and reported that increase in blanching time reduced the drying time of pregelled yam pieces. Muthu and Chattopadhyay (1982) suitably presented thin layer drying characteristics of parboiled rice by Page's model.

5.4. Packaging and storage of dudh churpi

Increase in titratable acidity might be the cause of microbial action by the aerobic spore counts or could be attributed to certain chemical reactions taking place during storage leading to the production of organic acids (Parry 1974).

The production of FFA was minimum when 0.1% potassium sorbate was incorporated into milk at the time of cooking and the samples were packed in a glass container. In khoa, peroxide value and FFA content increased consistently with storage period irrespective of the type of pouches used for packaging (Sharma *et al.* 1978). Similar observations were made in khoa (Narang 1969; Rudreshappa amd De 1971; Rao *et al.* 1977).

The change in tyrosine value which is an indication of proteolysis during storage of the samples is believed to be due to the survival of native as well as bacterial proteases which are not destroyed even by UHT processing (Lindquist 1970).

Browning increased steadily with storage time in control (unpacked) samples. But, in the samples packed in low density polyethylene (LDPE), high density polyethylene (HDPE) and glass containers there was a significant increase of browning only towards the later part of the storage. This could only be explained as a result of progression of the the Maillard browning reaction.

Decrease in sensory scores with the increase in storage period could be explained as a result of interactions of all the physico-chemical parameters discussed above.

The physico-chemical parameters and sensory attributes under all conditions decreased significantly ($P<0.001$) with the incorporation of sorbate in the samples. Potassium sorbate was the only chemical that was found to exert maximum inhibitory effect on microbial growth and maximum accelerating effect on keeping quality (Jha *et al.* 1977). Samples of dudh churpi with 0.1% sorbate packed in glass containers exhibited least change with respect to all the physico-chemical parameters and sensory attributes.

The quadratic regression model with correlation coefficient of more than 0.94 for moisture, free HMF, total HMF and reflectance with storage period holds good to explain the changes. These relationships are applicable upto the point of interest or upto the shelf-life of the product as the polynomial relationships can not be extended very much beyond the last data point.

Analysis of variance of mean overall acceptability scores of the product samples indicated that there was a significant ($P<0.001$) difference due to the use of packaged material and preservative. The shelf-life of the samples without sorbate and stored in glass container increased more than 4-fold over that of the control samples. The shelf-life of the samples enhanced almoct 8-fold when sorbate was incorporated in the samples stored in glass container over the samples without sorbate and stored traditionally. Shelf-life of khoa could be increased upto 10-11 days at 30°C by the incorporation of sorbate (Jha *et al.* 1977). The inhibitory effect of sorbate on microbial activity by inhibiting various enzymes, specifically those in citric acid cycle was reported by Lueck (1980).

The present study has shown that in order to get good quality dudh churpi from cow milk, it is necessary to cook prechurpi of 30% moisture level in milk of 1.0% fat, 8.7% SNF, 2.0% sugar and 29.25% total solids content for 15 min at 60°C. The cooked samples are to be dried in a drying chamber maintained at 35°C till a moisture level approximately of 15.00% is reached.

5.5. Water sorption characteristics of dudh churpi

5.5.1. Sorption isotherms of dudh churpi

The sorption process is of prime importance since many physical properties of macromolecular materials are greatly modified by the prescence of sorbed moisture. Dudh churpi is a porous and proteinaceous dairy product. Desorption and/or adsorption processes may alter its water sorption characteristics which control the texture profile of the product. Sorption isotherms are the graphical plots representing the relationship between equilibrium moisture content and water activity of a product. The isotherm drawn by joining the experimental data points showed the typical type II sigmoid shape common to most food product (Sawhney *et al.* 1991b). The typical sigmoidal shape of the isotherm of dudh churpi resembled the shapes of the isotherms of other dairy products, like caesin (Bandyopadhyay *et al.*1987), khoa (Sawhney *et al.* 1989) and paneer based convenience food (Rao 1993). Dudh churpi adsorption isotherm showed three regions of a typical isotherm as was reported in milk protien by Kinsella and Fox (1987). Water uptake is rapid in region I, slows down in region II and is accelerated in region III. Region I is represented by monolayer water which is strongly bound to proteins. Region II includes multilayer water which is under transition to natural properties of free water. Some of this water is available for chemical reactions. The water in region III is in free state, held in voids, crevices and capillaries (Kinsella and Fox 1987).

5.5.2. Equations describing isotherms of dudh churpi

Equations for fitting water sorption isotherms in foods are of special interest in many aspects of food preservation where dehydration is involved. Among them, are prediction of drying times, prediction of shelf-life of a dried product in a packaging material and also evaluation of the thermodynamic functions of the water sorbed in foods (Chirife and Iglesias 1978). Labuza (1968) discussed the selection and usefulness of isotherm equations.

Two major selection criteria for engineering calculations are accuracy and simplicity. For the prediction of drying times, or the shelf-life of packaged foods, the user is interested in an equation that fits closely to the experimental results rather than the correctness of the theory on which the equation is based. With these criteria in mind, nine equations were used in fitting the isotherm of dudh churpi and the goodness of fit was evaluated for each equation in terms of root mean square (RMS) value. It has been found that Caurie's equation was the best to characterize sorption behaviour of dudh churpi in full range of a_w. This equation is valid from zero a_w 0-0.85 for most foods (Caurie 1970).

5.5.3. Effect of temperature on isotherms of dudh churpi

Temperature of adsorption or desorption is known to affect the sorption characteristics of foods (Berlin *et al.* 1973). Temperature had considerable influence on sorption isotherm of dudh churpi. The effect of temperature on GAB isotherm parameters has been reported in soy protein, whey protein and sodium caesinate (Weisser 1985) and khoa (Sawhney *et al.* 1991b). In these products, Caurie's constants M_m and C decreased with increasing temperature.

Water sorprtion generally decreases with increasing temperature. When the temperature was increased from 24°C to 35°C, there was a decrease in water sorption in casein (Gal *et al.* 1962) and whey protein concentrates (Berlin *et al.* 1973). Noguchi (1981) stated that hydrophobic hydration of biopolymers melts off rapidly with rising temperature (20°-40°C). Similarly, hydration around the polar groups decreases by 50% during such a temperature rise, whereas electrostricted hydration around charged groups is less sensitive in this temperature range.

5.5.4. Properties of bound water and surface area of the adsorbent

The physical state of water in foods is most relevant to the product development since it influences the rate of physical, chemical, enzymatic and microbial changes that could occur in many foods. The bound water is of utmost importance because this water is reported to be unavailable either for microbial growth or for chemical reactions in foods (Caurie 1981). Some of the aspects of bound water in dudh churpi such as its density, its relation to surface area of adsorbent, number of adsorbed layers etc. have been studied in order to assess changes in the sorbed water caused by cooking and drying process of dudh churpi and temperature change. At lower a_w (0-0.3), moisture is strongly bound to hydrophilic, charged and polar groups of proteins. The water also gets hydrogen bonded to specific groups and plays an integral role in stabilization of protein molecules, and this water may also include that of hydrophobic hydration (Kinsella and Fox 1987).

It is interesting to note that the density of bound water decreases with the decrease in amount of bound water and surface area. This shows that the decrease in bound water content is not in proportion to the decrease in surface area. The density of normal free water is determined by distances between water molecules which are determined by the forces acting between the molecules. The closer the intermolecular distances, the greater are the forces acting between the molecules and, therefore, higher the density of water. When a monolayer of moisture is adsorbed on the surface of adsorbent, the intermolecular distances between water molecules are reduced and at the same time they are affected by surface forces of high magnitude which together alter the density of adsorbed moisture (Caurie 1981). In dudh churpi, the increase in sorption temperature resulted in considerable decrease in bound water, but did not cause proportional decrease in surface area.

This resulted in loose packing of water molecules causing corresponding decrease in density of sorbed water.

5.6. Consumer response to laboratory-made dudh churpi

Consumer response studies play a key role in developing a new or traditional food product. These are used as a tool to assess the performance of a food product, if introduced in consumer market. However, caution is advocated for depending solely on these studies because actual consumer response varies from region to region owing to several factors, like religious restrictions, familiar practices, experience and social and economic considerations. In fact, the reaction of respective consumer has to be gathered in the area in which the product is intended to be marketed.

The laboratory-made dudh churpi was highly acceptable by the chemical and sensory tests. But the consumers' opinion is vital in determining the actual acceptability of a product. The significance of reliable consumer opinion in product development can not be over-emphasized (Schaefer 1981). In the present investigation, the laboratory-made and the best quality market samples of dudh churpi were equally acceptable, indicating the potentialities of the innovations made in the present study in large scale production of dudh churpi.

5.7. Cost of production of dudh churpi

The cost analysis is always dependent on a number of variable factors and existing process facilities. An existing product plant can accommodate the production of dudh churpi for effective and economic utilization of the plant variables. This costing is also expected to generate interest among the existing dairy units to plan product diversification. It should encourage many unemployed and entrepreneurs in establishing small scale dudh churpi production centres.

It is revealed from the present investigation that dudh churpi is a protein-rich, highly nutritious and shelf-stable milk product. Dudh churpi prepared under optimized process conditions and suitably packed may be a highly profitable venture for small entrepreneurs.

Observed interrelationship between chemical and Instron texture profile parameters indicates the possibility of using a single parameter to know the product's texture which, in turn, will facilitate the quality control programme. This also leads to the possibility of dudh churpi as a nutritious substitute of chewing gum by minor alterations of the chemical parameters.

6. SUMMARY

Dudh churpi, a popular masticatory product, is traditionally produced from milk of Yak, dzno (a crossbreed of male yak and cow) and cow in Bhutan, Sikkim and Darjeeling, respectively.

The samples from Bhutan had least moisture, fat, water-dispersible protein, titratable acidity, pH and energy value than the samples from other two places. The values of these parameters are maximum in the samples of Darjeeling.

The samples from Darjeeling containing higher lactic acid, free fatty acid, 2-thiobarbituric acid, tyrosine and reflectance were less acceptable by the judges with respect to all the sensory attributes, and criticized those as rancid and brittle. Significantly poor sensory scores of dudh churpi prepared in Darjeeling might apparently be due to less heat treatment of green curd, and less cooking of prechurpi which resulted in hydrolysis of fat, protein and lactose. On the other hand, the samples from Bhutan rated highest with respect to all the sensory attributes and graded as the best quality product.

The samples from Bhutan containing high elasticity, firmness, smoothness, gumminess and chewiness but less crumbliness rated most desirable with respect to overall textural quality. The same also exhibited greater hardness, cohesiveness, springiness, gumminess and chewiness on instrumental analysis than those from Sikkim and Darjeeling .

Lactic acid, free fatty acid, 2-thiobarbituric acid, tyrosine and total 5-hydroxymethylfurfural combinedly reflected 68% variation in the total scores, and all the intrinsic parameters taken together explained 81% variation in colour and appearance scores.

Total solids, total fat, total protein, total sugar, titratable acidity and water-dispersible protein jointly explained 48% variation in hardness. Water-dispersible protein alone explained 41% variation in hardness which indicates the possibility of using a single, relatively simple parameter as an index of the instrumental texture profile.

All the Instron parameters taken together explained 47% variation of the overall sensory texture scores of dudh churpi, whereas the single parameter hardness predicted 55% sensory chewiness. The observed significant interrelationship between the sensory texture perception and instrumental mesurement can revolutionize the quality control programme leading to greater reliability blended with simplicity.

Successfully established psychophysical models could be of considerable importance for process modification of existing products. These necessitate predicting how the food system will react under certain conditions. This would be particularly relevant to traditional milk products, such as dudh churpi, which hitherto manufactured by traditional processes on small scales may be proposed to be produced on large scale by introducing this technological innovations.

Prechurpi was prepared in the laboratory by standardizing cow milk to 1.0% fat and 8.7% solids-not-fat, heating to 70°C, coagulating the milk within 60 s with hot (70°C) 2.0% citric acid solution, removing whey without any holding by filtering through a muslin cloth, cooking green curd in a boiling water bath for 20 min, wrapping hot cooked mass in a muslin cloth and pressing it at 9 kg/cm^2 for 12 h.

Best quality dudh churpi was prepared when pieces of prechurpi were smoked for 30 min, dried in an oven at 35°C to a moisture level of 30%, cooked for 15 min in milk of 1.0% fat, 8.7% solids-not-fat and 2.0% sugar concentrated to 29.25% total solids and dried in an oven at 35°C for 15-20 days.

The shelf-life of dudh churpi at ambient condition of storage was enhanced with the incorporation of 0.1% potassium sorbate in the milk used for cooking prechurpi and packed in glass/plastic containers or plastic pouches. However, the shelf-life was maximum in glass containers and minimum in pouches.

Adsorption isotherms of dudh churpi were typical type II sigmoidal isotherms according to BDDT classification. Nine equations, namely Bradely, Henderson, Iglesias and Chirife, Khun, Mizrahi, GAB, modified Mizrahi, Oswin and Caurie were fitted to the dudh churpi isotherm data. Caurie's equation was found to be suitable to predict equilibrium moisture content of dudh churpi. Monolayer value, density of sorbed water, number of monolayers and percent bound water decreased with the increase in temperature, and surface area of adsorbent reduced from 239.686 at 15°C to 214.016 m^2/g at 45°C.

Out of 254 respondents, 116 preferred laboratory-made dudh churpi and 105 preferred the best quality market samples of Bhutan indicating the equal acceptability of both the products.

Cost of production of dudh churpi was worked to be Rs 116.82 per kg. Calculated data on the cost of production of dudh churpi showed that conversion of 108 l cow milk into dudh churpi per day will help one to earn a net profit of Rs 96,584 per annum with capital investment of Rs 46,300 and operating cost of Rs 3,03,085 per annum.

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APPENDIX - I

Sorption ranges, constants and % root mean square (RMS) values of dudh churpi for selected equations at different temperatures

Equation	Temperature (oC)	a_w	Constants a	Constants b	% RMS
Bradely	15	0.1125-0.6800	44.7393	1.3116	7.517
		0.7560-0.9790	0.9645	1.0747	
	25	0.1125-0.3280	14.9142	1.2425	3.5052
		0.5290-0.9730	3.4259	1.1439	
	35	0.1125-0.3200	13.7940	1.2610	5.0069
		0.4990-0.9670	2.7913	1.1483	
	45	0.1115-0.4690	13.1892	1.3082	2.0934
		0.6700-0.9610	1.8402	1.1407	
Handerson	15	0.1125-0.3300	0.0000042	4.3145	8.2008
		0.5590-0.9790	0.0389	1.1832	
	25	0.1125-0.3280	0.000015	4.1124	3.9285
		0.5290-0.9730	0.0156	1.5328	
	35	0.1125-0.3200	0.000044	3.8180	4.8932
		0.4990-0.9670	0.0225	1.4640	
	45	0.1115-0.3105	0.000017	4.6092	7.5952
		0.4690-0.9610	0.0262	1.4612	
Iglesias & Chirife	15	0.1125-0.3300	2.2453	1.2727	5.8966
		0.5590-0.9530	1.4937	2.0662	
	25	0.1125-0.3280	2.0534	1.2972	7.0082
		0.5290-0.9730	1.3561	2.1477	
	35	0.1125-0.3200	1.9279	1.4068	8.2839
		0.4990-0.9670	1.2611	2.1189	
	45	0.1115-0.4690	1.7898	1.2509	4.5508
		0.6700-0.9610	0.3858	3.0267	

APPENDIX - I Continued

Equation	Temperature (°C)	a_w	Constants a	Constants b	% RMS
Khun	15	0.1125-0.5590	10.3260	-3.2152	6.9847
		0.6800-0.9790	17.8417	-0.8131	
	25	0.1125-0.5290	7.7888	-3.8052	8.0317
		0.6700-0.9730	17.2345	-0.5639	
	35	0.1125-0.4990	7.2091	-3.0529	7.5898
		0.6700-0.9670	14.7118	-0.6279	
	45	0.1115-0.4690	4.7135	-4.7948	8.6183
		0.6700-0.9610	11.7030	-0.7309	
Mizrahi	15	0.1125-0.5590	11.0471	-6.7464	9.4112
		0.6800-0.9790	16.2112	-15.1170	
	25	0.1125-0.5290	8.8528	-4.1593	8.0727
		0.6700-0.9360	3.8103	-12.4905	
	35	0.1125-0.4990	7.9850	-3.9952	5.9668
		0.6700-0.9070	11.9658	-10.6441	
	45	0.1115-0.4690	6.3366	-1.1566	4.8088
		0.6700-0.9610	10.6399	-9.5549	