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

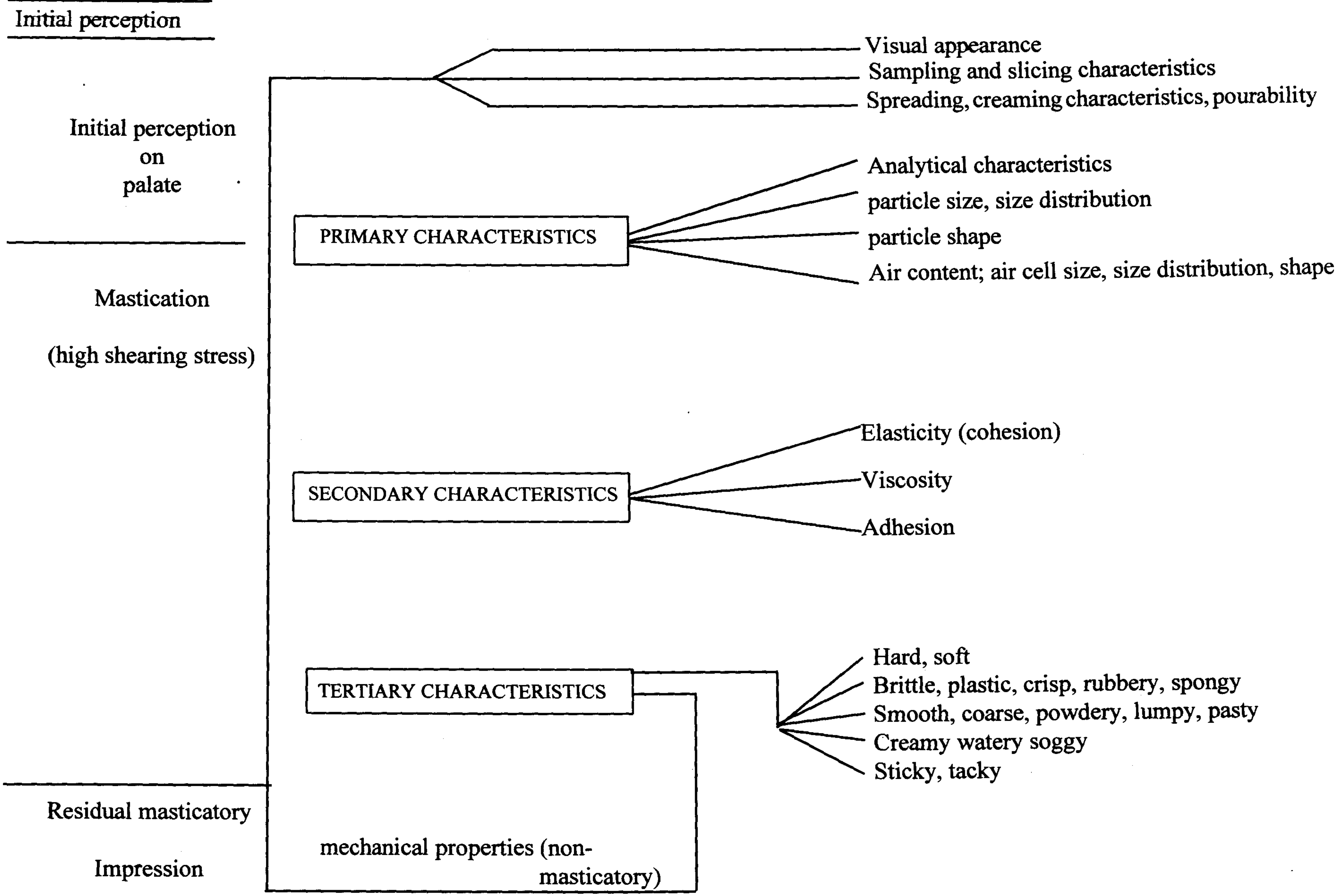

Fig. 1 The texture profile (Sherman 1969)

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:

$$MR = (M - M_e)/(M_o - M_e) = \exp[- Pt^Q] \quad \text{.........(10)}$$

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_0 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						
	Heat-ing	Freez-ing	Dry-ing	Salt-ing	Acidi-fication	Smok-ing	Inter-mediate-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.