2. REVIEW OF LITERATURE

2.1. Method of production of churpi

Chu-ra, 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 x 15 cm) laoves and then leaving to ferment at low temperature for several days. The loaves are sliced and the slices are strung on yak hair twine, and allowed to sun dry (Batra and Millner 1976).

The method of preparation of churpi or dokhra has also been described by Karki (1986). Yak milk is fermented under natural conditions and curdled by lactic acid production. Following separation of butter by churning, the butter-milk is coagulated. The liquid portion (water) is drained through filter cloth and the solid portion is placed on the cloth bag and allowed to drain the water slowly. The cloth bag is then closed by sewing all the sides and left for a few days. The solid material is then taken out from the bag and cut into big pieces. The churpi pieces are dried over wood-fired oven or under shade. The method of preparation of churpi has also been reported by Tamang et al. (1988). The cream is separated from cow or yak milk by cetrifugation, and the skimmed milk is boiled and curdled by adding whey. After filtration, the casein 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 sun dry for 2-3 weeks. Katiyar et al. (1991) reported a method similar to that reported by Tamang et al. (1988). However in the former, whole milk is used and the periodofsundrying is 3-4 weeks.

2.2. Proximate composition of churpi

Churpi (chu-ra) contains 2-4% moisture (Batra and Millner 1976). Katiyar et al. (1991) reported the mean chemical composition of churpi (per 100 g): moisture, 3.9-4.2 g; ash, 6.6-7.2 g; protein, 53.4-57.6 g; carbohydrate, 20.4-23.2 g; fat, 11.2-12.3 g; metabolizable energy, 407-411 cal; phosphorus, 733 mg; iron, 2 mg; potassium, 168-176 mg; sodium, 104-106 mg; and calcium, 70-76 mg.

2.3. Food texture terminology

2.3.1. Specific textural characteristics

Textural properties are classified into three main groups, namely mechanical, geometrical and other properties (Szczesniak 1963). Mechanical characteristics include five primary parameters (hardness, cohesiveness, viscosity, elasticity and adhesiveness) and three secondary parameters (fracturability, gumminess and chewiness) which are products of two or more primary properties. Elasticity was later defined as springiness (Bourne 1969). Primary properties, except adhesiveness, measure the response of food to stress and are related to the ability of food to resist disintegration under applied force (Szczesniak 1963). Geometric characteristics refer to the arrangement of the constituents of the food including size and shape as well as orientation of particles. Therefore, the gross and micro-structure of the food determines its geometrical properties. Other characteristics, such as moisture and fat content, describe the chemical composition of food. They also contribute to phenomena observed during instrumental analysis, such as lubricating ability. The physical and sensory definitions of mechanical characteristics (Table 1) were given by Civille and Szczesniak (1973) and have been accepted for texture profile analysis.

2.3.2. Sensory texture profile

Sensory texture profile is defined as "the organoleptic analysis of the texture complex of a food in terms of its mechanical, geometrical, fat and moisture characteristics, the degree of each present, and the order in which they appear from first bite through complete mastication" (Brandt et al. 1963). Szczesniak and her co-workers (Szczesniak 1963; Szczesniak et al. 1963; Brandt et al. 1963) proposed a sensory texture profile while developing a standardized methodology for evaluating the sensory texture of food. That profile was modified by Sherman (1969) as shown in Fig. 1. This profile is extremely useful when objective methods are not available.

2.3.3. Objective texture profile

Texture is composed of several inter-related parameters. This concept led to the development of a texture profile which accounted for changes in texture as a result of force, time and temperature variations (Larmond 1976). The texture profile was originally designed for mechanical assessment of texture based on sensory and objective measurements (Szczesniak et al. 1963) and uses the classification of primary and secondary properties described in section 2.3.1.

2.4. Instrumental measurement of food texture

Instrumental evaluation of textural properties is a complex problem, because the mechanics of evaluating rheological properties of foods is dependent upon a variety of test

Table 1. Definitions of textural characteristics

Properties	Physical	Sensory
Primary:		
Hardness	Force necessary to attain a given deformation	Force required to compress a substance between teeth
Cohesiveness	Extent to which a material can be deformed before rupture	Degree to which a substance is compressed between the teeth before it breaks
Springiness	Rate at which a material returns to its original condition	Degree to which a product returns to its original shape
Secondary:		
Fracturability	Force with which a material fractures	Force with which a sample crumbles or cracks
Chewiness	Energy required to masticate a food to a state ready for swallowing	Time required to masticate the sample to a state ready for swallowing
Gumminess	Energy required to disintegrate a semisolid food to a state ready for swallowing	Denseness that persists throughout mastication

Source: Civille and Szczesniak (1973)

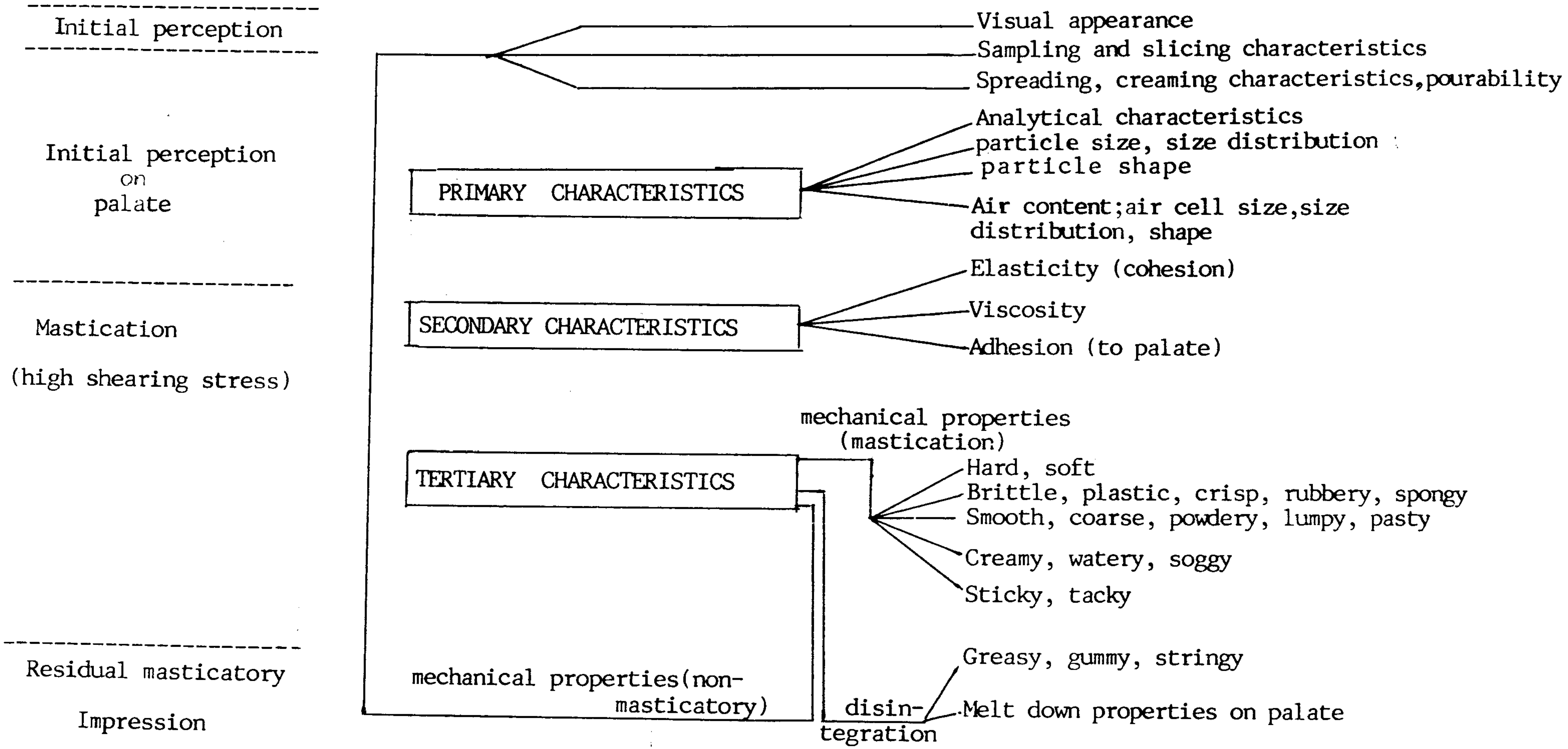

Fig. 1. The texture profile (Sherman 1969)

conditions, such as rate of loading, the magnitude of deformation imposed upon the material, geometry of the loading surface and localized yielding within the product tested (Finney 1969).

Literally, hundreds of instruments have been developed for measuring mechanical properties of foods. Many of these were designed specifically for a single food product or commodity. More recently, instruments of wider applicability have become available. Instruments, like Allo-Kremer Shear Press, General Food Texturometer, Ottawa Texture Measuring System, Universal Food Rheometer and the Instron Universal Testing Machine have gained considerable popularity because of their versatility, flexibility, accuracy and appealing design features. Since the studies of Bourne (1968), Instron has been used increasingly for measurements. Parallel plate uniaxial compression using Instron to obtain force-deformation curve is commonly used for food texture investigations (Olkku and Sherman 1979).

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

2.4.1. Compression testing with Instron

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

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

2.4.1.1. Test conditions

If reported conditions of obtaining Texture profile attributes (TPA) parameters are anything, they are inconsistent among different workers and food products. A major reason for inconsistency lies in the obvious differences which exists among different foods as to size of the largest unit, shape, homogeneity of structure and composition (Breene 1975). Effects of different test conditions on cheeses have been reported in the literature by several workers (Sherman 1976; Vernon _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). Lee _et_ _al_. (1978) found that the magnitude of response to various test conditions, particularly temperature, varied according to the type of cheese studied.

2.4.1.1.1. Sample size and shape

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

Theoretically, in a perfect test on an ideal material the stress-strain relationship in uniaxial deformation ought to be independent of the specimen dimensions by definition. In practice, especially in compressive tests of relatively flat specimens (i.e. height-to-width or height-diameter ratio of about unity or less), this is not always so, mainly because : (i) friction forces along the contact surfaces can become significant and, consequently, the specimen will exhibit considerably higher apparent strength and probably a different deformability pattern; several workers have suggested lubrication or other modification of the plates (Culioli and Sherman 1976; Montejano _et_ _al_. 1983; Casiraghi _et_ _al_. 1985; Bagley _et_ _al_. 1985a,b; Shinin 1987), and (ii) many food materials are fluid containing structures; in many cases, the stress level in a deformed specimen taken from such materials is largely a result of hydrostatic pressure build-up (Peleg 1987).

2.4.1.1.2. Size of compressing unit versus sample

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

2.4.1.1.3. Percent compression

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

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

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

2.4.1.1.4. Crosshead speed

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

2.4.1.1.5. Temperature

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

Awadhwal and Singh (1985), while developing a rheological model for paneer, used 15°C temperature for Instron measurements.

2.4.1.1.6. Number of bites

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

2.5. Sensory meaurement of food texture

Sensory evaluation is extremely valuable in the measurement of food texture because no instrument can preceive, analyse, integrate and interprete a large number of texture sensations at the same time. The pleasure centre in the brain plays a very important role in sensory evaluation. Even with strictly trained panels, which attempt to be as analytical and objective as possible, sensory evaluation of ten gives important information and psychological reaction to the product (Larmond 1976). Sherman (1970) expressed texture as the composite of those properties arising from the structural elements, and the manner in which they register with the physiological senses. The appreciation of texture involves the subble interaction between motor and sensory components of the masticatory and central nervous system (Jowitt 1974).

2.5.1. Perception of texture

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

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

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

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

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

2.6. Interrelationship between instruments and sensory assessment of food texture

Sensory and psychorheological models are important in texture studies. While sensory models, in general, imply a stimulus-organism-response design, psychorheological models consist of a mathematical expression relating sensory rheological data to the corresponding mechanical data. These two sets of data usually being considered as output and input, respectively (Drake 1979). Association between subjective and objective texture measurements may be expressed in graphical or mathematical terms.

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

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

Beyond developing a measure of relatedness of two variables, one can ascertain the relation itself using regression analysis. It has implicit in it the assumption of a unilateral casuality (Kapsalis et al. 1973). Regression analysis allows the experimenter to select a mathematical equation which is assumed to relate the two variables, and estimate the parameters of that equation (Moskowitz 1981). Often simple linear equations, as given below, adequately describe the sensory-instrumental relation (Moskowitz 1981):

$$S = k_o + k_1X_1 + k_2X_2 + \dots\dots\dots k_nX_n$$

where, S = Sensory response, and

$X_1 - X_n$ = Intensity of physical variables.

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

$$S = k_0 + k_1X_1 + k_2X_2 + k_3X_1X_2 + k_4X_1^2 + k_5X_2^2 + \dots\dots\dots (1)$$

$$S = k_0 + k_1X_1 + k_2X_2 + k_3^{(X_1/X_2)} + \dots\dots\dots\dots\dots\dots\dots (2)$$

$$S = k_0\ (e^{k_1X_1} + e^{k_2X_2} + \dots\ e^{k_nX_n}) \dots\dots\dots\dots\dots\dots (3)$$

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

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

$S = k\log(I) + C$ ......(4) where, S = Subjective magnitude and I = physical intensity. In semi-log co-ordinates the function becomes a straight line if the sensory rating is plotted as a function of the logarithm of physical intensity. the logarithmic function often appears when the panelist rates sensory intensity using a category scale. The equation 4 means that a ten-fold increase in physical intensity (I) produces a k unit additional increase in the sensory rating (Moskowitz 1981).

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

$$S = kI^n \quad ....(5)$$

Where, S = sensory intensity, I = physical intensity and k and n are parameters computed from the data (Kapsalis and Moskowitz 1979). The power function becomes a straight line after a simple transformation $\log S = n\log I + \log k$ .....(6).

Moskowitz (1981) suggested multistep approach to inter-relating hedonic performance judgement and instrumental measures involving following three steps: (1) develop linear or power equation which relate sensory to instrumental measures; (2) develop quadratic equation relating performance ratings; and (3) develop a combined equation.

As indicated by Moskowitz (1981), subjective-objective interaction for the food industry suggests a multistage process: (1) select the appropriate subjective attribute; (2) select the instrument measure or set of measures that produce sensory perception; (3) hypothesize candidate equations relating subjective and instrumental variables; (4) estimate the parameters of that equation by least square procedures; and (5) estimate the goodness of fit, the function to the actual data, by means of correlations and F ratios.

2.7. Texture of heat and acid coagulated Indian milk products

Chhana and paneer are the major heat and acid-coagulated indigenous milk products. Structurally, they are somewhat similar to certain soft cheeses. But, the distinctly different conditions of coagulation and removal of whey during their preparation, as compared to most cheeses, impart typical textures to this product.

2.7.1. Texture of chhana

Chhana of fine texture with velvety body is considered desirable (Warner 1951; Ray and De 1953). A compact, close-knit smooth texture (Rangappa and Achaya 1974) and a soft body are believed to ensure manufacture of good quality rasogolla, but a slightly less soft body together with smooth texture is desirable for making good quality sandesh (Ray and De 1953).

Gera (1978) studied rheological properties of cow, buffalo and skimmed milk chhana by adapting physical tests which included pitching number, penetration value, viscosity, springiness and density of chhana. Springiness was determined by an instrument developed for this purpose by Gera and Rajorhia (1979) who found that buffalo milk chhana was most springy followed by mixed milk (buffalo and cow milk, 1:1) and cow milk chhana.

2.7.2. Texture of paneer and soyabean curd

Buffalo milk has predominantly been used for paneer making

(Bhattacharya et al. 1971). Paneer from cow milk tends to be soft, weak and fragile as against firm, cohesive and spongy obtained from buffalo milk (Arora and Gupta 1980; Singh et al. 1984).

Texture profile of soyabean curd prepared by acid and salt coagulation was determined by Instron 6021 machine. The coagulants were acetic acid, citric acid, calcium sulphate and magnesium sulphate. Acid-coagulated soyabean curds exhibited greater hardness, springiness, gumminess and chewiness as compared to the salt-coagualated curds. The cohesiveness of different curds was practically the same (Vijayananda et al. 1988).

2.8. Different process parameters used in heat and acid-coagulated Indian milk products

Cow milk with 4.0% fat and 8.6% SNF produced chhana highly suitable for sandesh and rasogolla (De and Ray 1954). In a process modification, Kundu and De (1972) proposed homogenization of buffalo milk standardized to 5.0% fat before boiling and coagulating at 70°C employing 1.0% citric acid solution at pH 5.7.

The conditions of coagulations were studied by Iyer (1978) who suggested that good quality chhana could be obtained by coagulating cow milk at 70°C (pH 5.1) using 2.0% citric acid.

Kumar and Srinivasan (1982) reported that desirable quality chhana could be produced from buffalo milk by adopting conditions of coagulation and method of delayed straining as suggested by Kundu and De (1972), but excluding the homogenization step.

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

Singh and Ray (1977) studied the effect of coagulants on texture of cow milk chhana and noticed that citric acid coagulation (pH 5.77) produced chhana with soft and smooth texture, whereas lactic acid and sour whey produced chhana with hard and granular texture.

Bhattacharya and Desraj (1980) suggested the use of 0.8% citric acid, cooling the boiled cow milk to 80-90°C prior to coagulation, holding coagulated mass in whey for 5-10 min and cooling chhana mass in tap water for 20-30 min so as to obtain slightly firm, elastic and smooth textured chhana which was considered suitable for rasogolla making. Cooling the boiled cow milk to 80°C prior to coagulation with 2.0% lactic acid at pH 5.5 to 5.6 was successfully employed to yield desirable body and texture of chhana from cow milk (Kumar and Srinivasan 1982).

Chhana of desirable body and textural attributes, suitable for sandesh making by employing calcium lactate as coagulant has been obtained by Sen and De (1984).

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. Hot (70°C) 1.0% citric acid solution was added slowly to effect coagulation. Rao et al. (1984) obtained desirable body and texture in paneer, made from 6.0% fat buffalo milk, heated to 85°C and 0.3% citric acid by weight of milk. Vishwashwariah and Anantakrishnan (1986) produced desirable quality paneer by coagulating cow milk at 80°C with 2.0% citric acid solution.

Sachdeva and Singh (1988) standardized buffalo milk to a fat: SNF ratio of 1:1.65, heating to 90°C without holding, coagulating milk at pH 5.30-5.35 by using 1.0% citric acid solution. The resultant paneer had desirable textural attributes. Sachdeva and Singh (1987), while studying the effect of different non-conventional coagulants (namely hydrochloric acid, phosphoric acid, tartaric acid and acidophilus or sour milk whey) in the manufacture of paneer found that hydrochloric or phosphoric acid could be used in the manufacture of paneer without loss of its quality.

Shukla and Gill (1986) studied the effect of different acidulants on textural characteristics of paneer prepared from mixed milk (cow and buffalo). Use of citric acid gave a product with greatest hardness, while hydrochloric acid gave the lowest.

2.9. Cooking of raw paneer

Generally, 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 characteristics of raw paneer. Many researchers (Arora and Gupta 1980; Chawla et al. 1985; Sachdeva and Singh 1987, 1988) have evaluated the effect of frying and cooking on body and texture of raw paneer. However, these observations were based solely on sensory evaluation.

Arora and Gupta (1980) fried paneer (prepared from 4.0, 5.0, and 6.0% fat buffalo milk) in vegetable oil and noted that the body and textural differences observed in raw paneer narrowed down upon frying and all fried paneer samples were equally acceptable.

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

2.10. Quantum and duration of pressure in paneer making

Fortyfive kg weight for 15 min was employed by Bhattacharya et al. (1971) in paneer manufacturing using a hoop of 35 cm x 28 cm x 10 cm in size.

Kulshrestha et al. (1987) recommended a lower pressure (1-2 $kg.cm^{-2}$) with higher press time (100-200 min) for obtaining paneer of uniform quality in terms of moisture content and shear strength.

2.11. Drying characteristics of some foods

Ajibola et al. (1988) studied the effects of size, blanching time and drying temperature on the drying characteristics of pregelled yam pieces using a 2^3 factorial experiment. Page's model described adequately the drying behaviour of cassava pieces diced to 0.8 cm, blanched for 20 min and dried at 70°C reached a safe moisture content of 10.0% (dry basis) in 12 h.

Patil and Shukla (1990) conducted an experiment on open sun-drying of blanched soyabean and soya-split at different spreading densities of 3.25 $kg.m^{-2}$, 6.5 $kg.m^{-2}$ and 9.8 $kg.m^{-2}$. The whole clean soyabean and soya-splits were subjected to blanching in boiling water for 40 min to remove antinutritional factors. The variation in moisture content was monitored by weighing samples at every one hour interval during drying. The equivalent moisture content was determined as per following equation:

$$Me = B - \ln\{-(T + A)\} \ln RH$$

where, Me = moisture equivalent;

T = temperature;

RH = relative humidity; and

A and B are the coefficients evaluated from the data.

The net drying time for soya-splits was 7.5 h (<1 day), 12 h (<2 days), 13 h (<3 days), and for whole soyabean was 12 h (<2 days), 12.5 h (<2 days) and 15.5 h (3 days) at spreading densities of 3.25, 6.5 and 9.8 $kg.m^{-2}$, respectively.