5. DISCUSSION

5.1. Survey on traditional methods of churpi preparation

The co-operative milk unions of Bhutan, Sikkim and Darjeeling procure milk through primary co-operative societies at different villages of these areas where motorable road facility exists. But, thousands of milk producers of remote villages still can not pour their surplus milk into primary co-operative societies due to topographical constrains. Milk which is unprocessed and held at ambient temperature will have a shelf-life up to 5 h. To preserve milk solids, the milk producers of those places convert their surplus milk into deshi butter and churpi. Churpi is believed to be highly nutritious, energy-giving and a self stable product (SSP). It can be shelved up to one year. Churpi therefore provides a vehicle for preserving the valuable nutrients in milk and making those nutrients available throughout the year. During mastication, churpi helps in greater amylase secretion which in turn provides higher activation energy during up-hill trekking.

5.2. Analysis of market churpi

5.2.1. Physico-chemical analysis

Wide variation in the contents of moisture, fat and protein in the market samples of churpi from different sources was likely due to the difference in type of milk, method of separation and treatment of the curd. 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. Nasir _et al_. (1987) reported the presence of appreciable amount of lactose in the market samples of chhana. Katiyar et al. (1991), however, reported 3.9 to 4.2% moisture, 11.2 to 12.3% fat, 53.4 to 57.6% protein, 20.4 to 23.2% carbohydrate and 6.6 to 7.2% ash in churpi of Sikkim. In the present study, free fat of market churpi ranged between 17 and 23% of the total fat. High content of free fat in the samples of churpi may be explained as the combined action of scrapping and agitation during cooking of the green curd. 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 churpi varied from 5.7 to 12.3% of the total protein content. The higher WDP in the churpi 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 consequently less hard churpi. In laboratory-made khoa samples, the WDP content was reported to be 8.5 to 28.7% of total protein (Gupta et al. 1990).

Among the milk and milk products, only cheddear cheese which gives about 0.096 MJ/100 g energy (De 1980) is comparable to the energy value of churpi.

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

Estimation of tyrosine value is one of the measures to determine the degree of protein hydrolysis in milk and milk products. 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 churpi. Severe heat treatment during preparation of 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 (Hansen 1967), 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. It was evident from Table 6 that the samples of churpi of Darjeeling 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 and also storage conditions. Higher concentration of HMF in milk leads to development of off flavour and discolouration. 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). Samples of Sikkim with maximum HMF content resulted in minimum reflectance, whereas samples of Darjeeling with least HMF content showed maximum reflectance. Higher reflectance could be explained by the formation of melanoidin during heat treatment which interferes passage of light through the samples. Higher HMF values 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 oxidises 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 acumulation (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). Prolonged drying at elevated temperature might further be responsible for higher HMF values.

5.2.2. Relationship between sensory attributes and intrinsic parameters of market churpi

High negative correlation (P<0.001) of flavour scores with FFA and TBA (Table 10) is presumably associated with the autooxidative products of unsaturated fatty acids, mainly oleic, linoleic and linolenic together with phosphplipids. The preponderance of carbonyls also imparts specific flavours. It was observed that quantity of carbonyls in painty butterfat was much greater than in fishy, though the qualitative composition was rather similar. These compounds, even at subthreshold concentrations, compositely give rise to a characteristic oxidized flavour (Kinsella et al. 1967). The protein-carbohydrate complex or its decomposition products results in the production of reducing substances, fluorescent substances and disagreeable flavour materials (Nickerson 1974). On the contrary to this report, a high positive correlation ($P<0.001$) of free and total HMF with flavour scores (Table 10) was observed in the present investigation. This was due to the typical flavour profile of churpi.

High positive correlation ($P<0.001$) of body and texture scores with p-DMAB and HMF may be explained on the basis of heat treatment of green curd during preparation of churpi. Higher heat treatment provides greater activation energy to form higher amount of free plus potential HMF (Berk 1976). Heating also increases the protein-protein interactions in the suspension at relatively high concentration, and this is accompanied by an increase in consistency and curding or aggregation (Saio et al. 1968; Catsimpoolas et al. 1969, 1970) leading to higher compactness. High tyrosine content indicates extensive protein hydrolysis. In cheddar cheese, hydrolysis of protein causes the body of the cheese to lose its firm, tough, curdy properties and becomes soft and mellow. During this progressive proteolysis the paracasein and the minor proteins are gradually converted to simpler nitrogenous compounds, namely proteoses, peptones, amino acids and ammonia (Ernstrom 1974). Soft and mellow body was not desirable in churpi, and hence a high negative correlation (P<0.001) was observed with body and texture scores and tyrosine content.

Singh and Patil (1988) reported a negative correlation of HMF values, TBA values and acid degree values with flavour scores in a storage stability study of UHT buffalo milk.

5.2.3. Relationship between chemical composition and instron parameters of market churpi

It is evident from Table 12 that hardness of churpi is positively correlated with total solids, whereas WDP showed a negative correlation with hardness. This indicated that total solids in churpi contributed to the strength of the solid network. Higher WDP meant that a only smaller portion of the total protein was transferred to the solid network resulting in lower strength, and hence was the formation of less hard churpi. This can also be explained in the light of heat induction. Heat induces an increase in entropy of a system. Thermal denaturation of protein is a combination of coulombic repulsion and thermal vibration which causes an inelastic stretching of the parts of the protein molecules (Joly 1965). Thus during preparation of churpi, where green curd was subjected to less heat treatment, the final product had a lower strength with low total solids and high WDP content.

Cohesiveness of churpi had a high positive correlation with total solids and total protein, and was found to be negatively correlated with fat, free fat, titratable acidity and WDP. Cohesiveness is basically a phenomenon of intermolecular attraction. Churpi undergoes a varying degree of heat treatment during its preparation which hastens expulsion of whey, causing increased compactness. As the heating progresses total solids content also increases and more soluble protein is transferred to the solid network resulting in higher total solids, lower WDP and increased compactness. One of the important thermal effects on protein is that heating increases the protein-protein interactions in the suspension at relatively high concentration, and this is accompanied by an increase in consistency and curding or aggregation (Saio et al. 1968; Catsimpoolas et al. 1969, 1970). Contrary to this observation, Gupta et al. (1990) reported negative correlation of cohesiveness with total solids, fat and protein and positive correlation with WDP content of khoa. Fat, free fat and titratable acidity presumably cause a declining effect in the interparticle binding causing a less cohesive churpi.

The significant impact of compositional variable on instron textural parameters provides ample information in determining textural characteristics of the product. No literature is so far available on such interrelationship of churpi. Keller et al. (1974) reported the correlation of moisture contents and rheological properties of mozzarella cheese. Gupta et al. (1990) studied the impact of compositional variables on instron textural parameters of khoa. Desai (1988) observed significant correlations between moisture content and instron texture profile parameters for chhana. Gupta et al. (1984) found significant correlations between instron hardness and other parameters, except cohesiveness, in different types of processed cheese foods.

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

Parry and Carroad (1980) observed excellent correlations between sensory and instrumental firmness of cottage cheese. Significant correlations between sensory firmness and instron hardness had also been observed in khoa (Patil et al. 1990) and chhana (Desai 1988) and to a less extent in paneer (Desai 1988).

It was observed in churpi that instrumental springiness in combination with hardness and cohesiveness predicted better firmness than what it could predict alone (Table 15: equations 5, 7). Thus, churpi with greater hardness and cohesiveness tended to be more springy. A similar observation was made in khoa by Patil et al. (1990) where it was reported that a more granular khoa tended to be more springy.

A significant correlation between instrumental and sensory chewiness for khoa (r = 0.46) was reported by Patil et al. (1990). Desai (1988) reported a higher correlation for chhana (r = 0.82) and a considerably lower correlation for paneer (r = 0.55). It should, however, be noted that 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, exhibit chewiness more at the particle level than at the bulk level. This time, jaws crushing the piece or bulk come close to each other so that individual grains are crushed. Thus, although the chewiness of individual granules may contribute some of the chewiness of the bulk, it is mainly the hardness, cohesiveness and springiness of these granules that should determine the sensorily perceived chewiness (Patil et al. 1990). Hence, the instron chewiness need not necessarily reflect the sensory chewiness of structurally particulate products such as churpi.

In the present psychorheological model involving the consideration of relations between instrumental and sensory data, it can therefore easily be used for simulation. The result of such a simulation can be utilized for prediction of sensory properties from a knowledge of mechanical properties (Drake 1979).

Investigations on market churpi indicated that the churpi prepared in Bhutan was highly accepted with respect to sensory, chemical and instrumental data. Significantly poor sensory scores of churpi prepared in Darjeeling might apparently be due to higher fat, protein and lactose hydrolysis. Significant impact of intrinsic parameters and compositional variables on sensory attributes and instron textural parameters respectively provided ample information in determining sensory acceptability and textural characteristics of the product. These interrelationships also indicate 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 programmes. Significant interrelationship between the sensory texture perception and instrumental measurement can also revolutionize the quality control programmes 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 churpi, which hitherto manufactured by traditional processes on small scales may be proposed to be produced on large scales by introducing these technological innovations.

5.3. Optimization of process parameters

5.3.1. Fat level in milk

Flavour is generally judged as the total physiological response, and for practical purposes this is calibrated against physico-chemical analysis (Kinsella et al. 1967). The agreeable flavour of rich milk and of other dairy products is largely due to the milk fat (Eckles et al. 1973). Flat flavour in skim milk churpi is probably due to negligible amount of fat content in churpi. Churpi prepared from milk having 1.0 and 1.5% fat might be associated with carbonyls. Carbonyls, even at subthreshold concentrations, compositely give rise to a characteristic oxidized flavour (Day et al. 1963). Higher TBA values of these samples further justifies this statement (Sidewell et al. 1955).

Churpi samples prepared from skim milk exhibited greater instron values compared to the samples prepared from milk of other fat levels. Higher protein content in skim milk churpi exhibited greater aggregation of protein molecules and so higher instrumental values.

Flavour attribute of churpi, prepared from skim milk, scored less due to negligible amount of fat present in churpi. Again, churpi prepared from 1.5 and 2.0% fat milk also had a lower flavour score due to the association of higher FFA and TBA values. Samples of churpi, prepared from 1.0% fat milk, showed greater potentiality with respect to all the sensory attributes and chemical parameters. Sensory, chemical and instrumental data of churpi samples prepared from 1.0% fat milk closely resembles to the similar data of best available market churpi of Bhutan. Hence, 1.0% fat in milk was considered the optimum fat level of milk for preparation of churpi.

5.3.2. Temperature of coagulation of milk

Hardness, cohesiveness, springiness, gumminess and chewiness are the most important criteria in determining the textural quality of churpi. Samples of churpi prepared from milk coagulated at 70°C showed better instrumental value than the samples prepared from other coagulation temperatures. These values were found even better than the best quality market samples of Bhutan. Iyer (1978) suggested that good quality chhana could be obtained by coagulating cow milk at 70°C (pH 5.1) using 2% citric acid. Thus, heating of standardized milk upto 70°C and its immediate coagulation at that temperature was found optimum for preparation of churpi.

5.3.3. Method of straining

The instrumental hardness, cohesiveness, gumminess and chewiness were maximum in churpi made by immediate straining method. The values decreased with increase in holding time of the coagulated mass in whey. Since the delayed straining causes the coagulated mass to retain more moisture than immediate straining (De 1980), the moisture content and the yield of churpi prepared by delayed straining methods were significantly ($P<0.05$) higher than the samples prepared after immediate straining. Immediate straining of coagulum yielded a product of desired textural quality. Hence, immediate straining was found the optimum condition for the preparation of churpi.

5.3.4. Strength of citric acid

Citric acid (1.0%) is conventionally used in the manufacture of paneer and chhana (Bhattacharya *et al.* 1971; Kundu and De 1972). There are reports mentioning the use of stronger solutions in the manufacture of chhana and paneer (Iyer 1978; Sachdeva *et al.* 1985). Solutions of lower strength would increase the bulk of the content, posing problems in handling, and hence was not included in the present study. Thus, 2.0% citric acid was conveniently used for the preparation of churpi.

5.3.5. Type of coagulant

Different concentrations of coagulants were tried initially. Tartaric acid solutions of different concentrations, viz. 1.0, 1.5 and 2.0% were used. This coagulant, above 1.5%, imparted an acidic flavour. Hence, 1.5% level of tartaric acid was used.

Sour whey, a by-product of churpi manufacture, was used as a coagulant to effect economy. When the whey was soured overnight at 30°C and used as such, the amount required to coagulate was too much to handle. To cut down the bulk and also to reduce the amount of citric acid, citric acid was dissolved in sour whey instead of water.

The use of tartaric acid (1.5%) and citric acid (1%) in sour whey did not give rise good quality churpi. Churpi prepared from 2% lactic and 2% citric acid were equally acceptable with respect to sensory scores and instrumental data, but the yield of churpi prepared by using 2% lactic acid was significantly ($P<0.05$) higher than using 2% citric acid solution. However, to effect economy, 2.0% citric acid solution can conveniently be used for the preparatiion of churpi.

5.3.6. Cooking of green curd

Higher moisture ratio reduction at the beginning of cooking process may be attributed to the higher moisture potential available for removal. The rate of reduction decreased as the replenishment of water from interior to the surface of the curd did not cope up with the fast removal of moisture at the surface.

Higher sensory elasticity or instrumental springiness at moderately high moisture ratio may be explained on the basis of protein aggregation. When a large number of protein molecules is involved in the interaction in a discrete manner, or if the intermolecular interaction density is high, the aggregate reduces hydration, surface area, and partial specific volume. On the other hand, if the interaction between molecules includes few cross-links in the manner of bead-string, and especially if this interaction stretches the molecules themselves, the aggregation will increase in their hydration and partial specific volume and also attain more flexible and elongated structures (Lee and Rha 1979).

Linear relationship of p-DMAB reactivity with instrumental hardness and cohesiveness and sensory firmness, smoothness and crumbliness can be explained on the basis of protein-protein interactions. One of the important thermal effects on protein is that the heating increases the protein-protein interactions in the suspension at relatively high concentration, and this is accompanied by an increase in consistency and curding or aggregation (Catsimpoolas et al. 1969).

Cooking of the curd was therefore continued up to 20 min in a boiling water bath, since further heating implied no significant effect on sensory or instrumental textural qualities of churpi. Churpi samples of Darjeeling were found to be associated with lower sensory and instrumental values and higher intrinsic values due to lack of heat treatment of the green curd. Thus, cooking of the green curd helped in the destruction of undesirable microflora, in the alteration of protein structure and in the improvement of sensory acceptability of the product.

5.3.7. Pressing condition

Intersection of curves indicated the following mechanism of moisture expulsion:

As pressure is applied, a hydraulic gradient is established in the sample and water starts migrating radially, towards the perforated walls of the press. Along with water, finer particles may also be transported and may get deposited in the outer pores. Consequently, porosity in the outer zone is reduced and further expulsion of water is restricted although excessive moisture is present in the central zone. At higher pressures, the velocity of water and hence that of the particles, is more. Therefore, the permeability of peripheral zone my be reduced to the extent of formation of an impervious layer. In this case, further expulsion of water shall be restricted though excessive moisture and sufficient hydraulic pressure are present in sample. Consequently, the ultimate moisture ratio reduction, in case of higher pressures, is less (Kulshereshtha et al. 1987).

The observations on cohesiveness may again be explained on the basis of particle transport. Cohesiveness is basically due to the interlocking of particles. Since interlocking itself is a function of compaction of sample, the increase in cohesiveness with time may be said to be due to the compaction of the sample. As pressure is increased, more and more particles move away from the central zone and the interlocking of particles in the central zone weakens. Consequently, cohesiveness strength of the central zone decreases with increase in pressure (Kulshreshtha et al. 1987).

The observations on springiness may also be explained on the basis of the phenomenon of cohesiveness. For pressing times greater than 6 h, springiness decreased as pressure was increased. At higher pressure-time combination the interlocking of particles in the central zone weakens. Consequently, cohesiveness and springiness of the central zone decrease.

The variation in moisture content, cohesiveness and springiness with pressing conditions can be expressed by mathematical relationships, and pressure of 9 $kg.cm^{-2}$ for longer time was more suitable for preparation of churpi.

5.3.8. Drying behaviour as effected by size of churpi

Higher rate of drying at the beginning of the experiment can be attributed to the higher moisture potential available for removal at the beginning of the drying process. The rate of drying decreased as the replenishment of water from interior to the surface of churpi could not cope up with the first removal of moisture from the surface.

The relationship between the drying rate and size of churpi revealed that the rate of drying was higher for smaller sizes of churpi. However, since there was no significant ($P<0.05$) difference in instron parameters of the samples of churpi of different sizes, the size of churpi has no effect on its body and textural characteristics.

No literature is available on drying characteristics of churpi. Ajibola *et al*. (1988) adequately represented drying data by Page's model and reported that increase in blanching time reduced the drying time of pregelled yam pieces. Muthu and Chattopadhyay (1992) suitably expressed thin layer drying characteristics of parboiled rice by Page's model.

The present study has shown that in order to get a good quality churpi from cow milk, it is necessary to standardized milk to 1.0% fat and 8.7% SNF, heating milk to 70°C and coagulating with 2.0% hot (70°C) citric acid solution. The coagulum is to be removed immediately from whey, without any holding, filtered through a muslin cloth, and the green curd be cooked for 20 min in a boiling water bath. The hot cooked curd is to be wrapped in muslin cloth and pressed at 9 $kg.cm^{-2}$ for 12 h before drying over wood-fired oven for 40-50 days.

5.4. Consumer response to laboratory-made churpi

Consumer awareness and preference decide the success of a food product. Besides the sensory attributes of the food, other factors like religious restrictions, familiar practices, experience, and social and economic considerations have a great impact on food selection and use.

The laboratory-made churpi was highly acceptable by the chemical and sensory tests. But the consumers' opinion is vital in determining actual acceptibility 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 churpi were equally acceptable, indicating the potentialities of the innovations made in the present study in large-scale production of churpi.

5.5. Changes in sensory attributes and physico-chemical parameters during manufacturing churpi

A steady increase in FFA content during drying of churpi could be attributed due to the fat hydrolysis by exocellular lipases of pseudomonads which are not inactivated even after UHT processing (Renner 1979).

Gradual increase in TBA value could be associated with prolonged drying at elevated temperature and in open air (Wadsworth and Bassette 1985). Minor saturated and unsaturated aldehydes and autooxidation of dairy product also could lead to a multitude of saturated and unsaturated aldehydes resulting in higher release of TBA values (Kurtz 1974).

Tyrosine content of 0.15 mg/g in matured churpi which is much less compared to fermented dairy products (Vema and Anand 1987) indicated little or no evidence of protein hydrolysis. In cheddar cheese, lactose was reported to be completely hydrolysed within 30 days of curing (Vema and Anand 1987). Matured churpi with 0.03% lactic acid eventually showed no evidence of hydrolysis of milk sugar.

Higher HMF values at the onset of drying could be attributed due to open pan heating of green curd with constant stirring (De 1980; Golubonic _et al_. 1983; Nagendra _et al_. 1991). Prolonged drying at elevated temperature might further be responsible for increase in HMF values.

It is evident from Table 34 that titratable acidity, lactic acid, FFA, TBA and tyrosine had an important role on sensory attributes of churpi. In cheddar type cheeses, fat fraction contributed more to the development of flavour than any other component, although milk proteins and lactose are sources of many flavour precursors (Ohren and Tuckey 1969). The development of characteristic churpi flavour complied this report. The characteristic hard body of churpi is due to minimum degradation of protein as evident from tyrosine value. Higher soluble nitrogen in cheese indicates higher degradation of proteins into simpler compounds resulting in mellow body. High correlation ($P<0.001$) of THMF with colour and appearance scores of churpi could be associated with the formation of a brown pigment, melanoidin.

5.6. Cost of churpi production

The cost analysis is always dependent on a number of variable factors and existing processing facilities. Each plant will have some spare capacity which could be put to economic use in the production of churpi. This is particularly applicable to services, utilities, building, equipment and to some extent to the proper utilization of manpower and administrative set up. Many dairy plants in India do not work to their full capacity. Each may have one or many constraints in economic functioning. This costing is expected to generate interest among the existing dairy units to plan product diversification. It should encourage many unemployed and young entrepreneurs in establishing small scale churpi production centres.