TECHNOLOGICAL AND BIOCHEMICAL INNOVATIONS IN MANUFACTURING CHURPI — A TRADITIONAL SOUTH-EAST ASIAN MILK PRODUCT

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Certified that the work presented in the thesis entitled, "Technological and biochemical innovations in manufacturing churpi - a traditional south-east Asian milk product" has been carried out by Mr Pradip Kumar Pal, M.Sc. under my supervision at the Department of Botany, University of North Bengal. The results incorporated in the dissertation have not been submitted for any other degree elsewhere.

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

Dr P.K. Sarkar

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CONTENTS

1. INTRODUCTION

Traditional foods are based on culture, custom and natural environment of a region of the world, and consumed by the people for a long time (Watanabe 1986). A variety of traditional foods, such as kinema, gundruk, sinki, mesu, churpi, shel-roti and jnards in Darjeeling district of West Bengal and the state of Sikkim (Tamang et al. 1988), chu-ra in Tibet (Batra and Millner 1976) and dokhra or churpi in Nepal (Karki 1986) are prepared and consumed by various ethnic groups. Approximately 70% inhabitants of the Darjeeling district and about 90% in the state of Sikkim (a total of about 1.15 million) consume large quantities of traditional foods and beverages. Some ethnic groups are economically dependent upon these local products (Tamang et al. 1988).

Churpi is a popular traditional milk product of Darjeeling hills, Sikkim (Tamang et al. 1988), Nepal (Karki 1986) and Bhutan. It is prepared by the combined action of acid and heat treatment of milk and curd. Karki (1986) defined churpi as " a hardened cheese in the form of cubes and consumed by biting or chewing as betelnut". The product, sold in the markets of Darjeeling hills, Sikkim and Bhutan as light amber to dark brown coloured cubical or cylindrical blocks and used as masticatory, is faintly sweet and distinctly smoky with very hard and compact body. The interesting characteristic of churpi is its pronounced gumminess and chewability.The origin of churpi making is lost in unrecorded history. Preparation of churpi in Bhutan is controlled by "Dukpa" community. But in Darjeeling and Sikkim, it is prepared by the villagers irrespective of caste and creed.

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

Sensory evaluation of texture in foods belongs to the domain of psychology known as psychophysics that directly concerns the correlation of sensory experience with physical measures (Moskowitz et al. 1973). Successfully established psychophysical models could be of considerable significance also to the development of new or imitation products and process modifications for existing products. These necessitate predicting how the food system will react under certain conditions (Patil et al. 1990). This will be particularly relevant to indigenous milk products such as churpi which, hitherto manufactured by traditional processes only on cottage scale, may be scaled up by introducing technological innovations.

The consumers of Indian traditional milk products are subjected to varied tastes and textures. But, little is known about the desirable sensory and chemical properties of these products. Thus, there is an urgent need for determining the quality parameters for these products.

Realizing the popularity and importance of Indian traditional milk products, a need for suitable technologies for commercial production of products with uniform quality had been emphasized by the National Commission on Agriculture (1976). Actions have also been initiated by the Food and Agrilcultural Organization of the United Nations for upgrading the traditional technologies for food conservation and processing (Faure 1986).

Keeping the above points in view, churpi, which is one of the most popular traditional milk products of several parts of south-east Asia, has been chosen for the present study with the following objectives:

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

(b) assessing the physico-chemical qualities and sensory attributes of market samples of churpi prepared in Darjeeling hills, Sikkim and Bhutan;

(c) elucidating the rheological and sensory textural properties of market samples of churpi;

(d) correlating sensory attributes with some intrinsic parameters of churpi;

(e) studying the influence of composition on the Instron texture profile of churpi;

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

(g) optimizing different process parameters in the preparation of churpi from cow milk;

(h) studying the sensory and physico-chemical changes during the production of churpi; and

(i) evaluating the cost of production of churpi.

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)

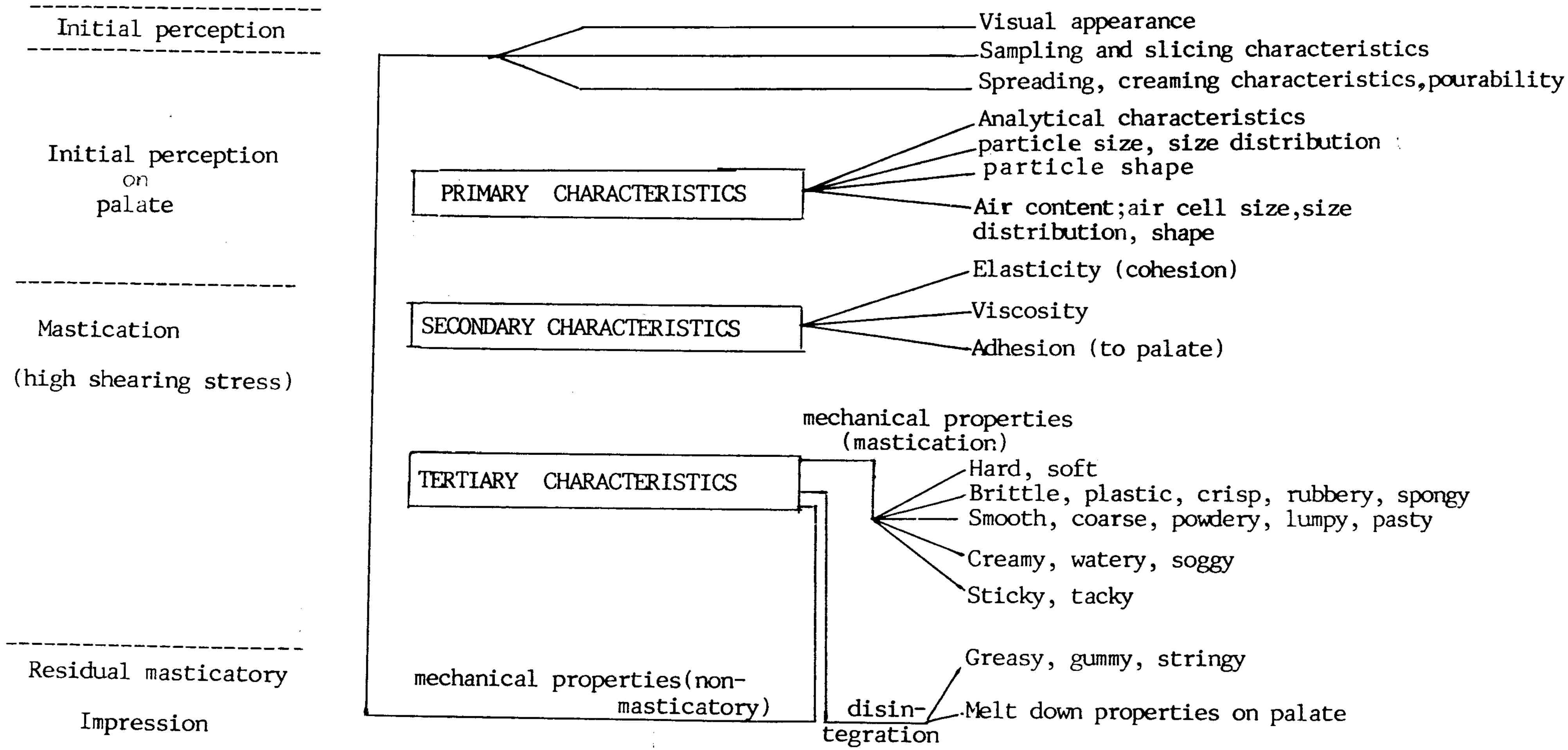

Fig. 1. The texture profile (Sherman 1969)

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 <u>et</u> <u>al</u>. 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:

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

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

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

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

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

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.

3. MATERIALS AND METHODS

3.1. REAGENTS USED

Ammonium molybate solution

6% w/v $(NH_4)_6Mo_7O_{24}.4H_2O$ in distilled water

Barium chloride solution

9.88% w/v $BaCl_2$ in distilled water

p-Dimethylaminobenzaldehyde solution

4% w/v p-dimethylaminobenzaldehyde in chloroform

Ferric chloride solution

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

Glycine-sodium hydroxide buffer

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

Methylamine solution

5% w/v methylamine-HCl in distilled water

Mixed indicator solution

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

Phosphate-phthalate buffer

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

Sodium carbonate-sodium tetraphosphate solution

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

Sodium hydroxide-sodium thiosulphate solution

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

Sodium sulphite solution

1% w/v Na_2SO_3 in distilled water

Zinc acetate-phosphotungstic acid reagent

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

Zinc sulphate solution

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

TBA reagent

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

All the chemicals used were of the highest purity grade.

3.2. EXPERIMENTAL

3.2.1. Survey on churpi

A survey was conducted in the villages of Bhutan, Sikkim and Darjeeling hills to get detailed information on the types, traditional methods of preparation, modes of consumption, cost of production and market prices of churpi used by the local people.

3.2.2. Collection of market samples

Samples of churpi were purchased from different shops of Phuntsholing (Bhutan), Gangtok (Sikkim) and Darjeeling (West Bengal). They were packed in clean stainless steel containers with tightly closed lids. The containers were transported immediately to the laboratory for analyses.

3.2.3. Physico-chemical analysis of market churpi

3.2.3.1. Reflectance

Colour of churpi was measured in terms of reflectance at 450 nm using a Reflectometer (Elico, type CL-28, India) against magnesium block which gives 100% reflectance.

3.2.3.2. Chemical analysis

Samples of churpi were broken into small pieces with the help of heavy cutter and pestle. The pieces were then powdered by using a grinder (Bajaj, India).

3.2.3.2.1. Moisture

A sample of ground churpi (ca 2 g) was accurately weighed into a cooled and weighed tared dish, previously heated to $130 \pm 1\,^{\circ}C$. The sample was allowed to dry for 1 h at $130 \pm 1\,^{\circ}C$ in a hot air oven. The dish was covered while still in oven, transferred to a dessicator, and weighed soon after reaching room temperature. The process of drying, cooling and weighing was repeated until the two successive weights reached a constant value. Moisture content was calculated by subtracting the final weight from the initial weight (AOAC 1990).

3.2.3.2.2. Total fat

The method as described in SP : 18 (Part XI) (1981) was followed. Approximately 5 g accurately weighed ground sample was placed in about 10 ml concentrated hydrochloric acid containing in a beaker. Ten ml hydrocholoric acid was further added to wet and wash down any particles of the material that might have adhered to the sides. The contents were heated over a burner so that all particles of the material adhering to the sides of the beaker are dissolved in the acid. The contents were finally boiled for 10 min and allowed to cool to room temperature (ca 25°C). The contents were quantitatively transferred to a Röse-Gottlieb fat extraction tube using about 10 ml of acid as wash liquid. Twenty-five ml of diethyl ether was added to the beaker and transferred the contents to the tube. Twenty-five ml of petroleum ether was added to the beaker and transferred to the tube which was then stoppered with a bark cork, shaken vigorously and allowed to stand until the upper liquid was clear. The ether solution was decanted into a preweighed Erlenmeyer flask. The extraction was repeated using both the solvents in equal parts. The solvent was evaporated completely on a steam bath. The fat was dried in an oven at 100±1°C to constant weight.

3.2.3.2.3. Free fat

The procedure recommended by Hall and Hedrick (1971) for milk powder was followed for churpi. Ten g of ground churpi was taken in a 250 ml Erlenmeyer flask. Hundred ml petroleum ether was added in it and shaken with a vertical motion for 10 times. The contents were allowed to settle for 15 min and filtered through

Whatman No. 42 filter paper catching the solvent in a tared Mojonnier fat dish. A second extraction was also exercised following the same procedure. The etheral layer was evaporated in a hot air oven at 100±1°C and the sample weight was determined.

3.2.3.2.4. Free fatty acid

The free fatty acid content in churpi was determined as per IS : 3508 (1966) with minor modifications. An accurately weighed (ca 5 g) ground sample was mixed with 25 ml 95% ethanol neutralized previously by 0.1 N NaOH, using phenolphthalein (0.01% w/v in 95% ethanol). The solution was heated to boiling on water bath and filtered through Whatman No. 1 filter paper. The filtrate was titrated with 0.1 N NaOH until a pink colour persisted.

$$\text{\% Fatty acid content (as oleic acid)} = \frac{100 \times \text{ml of NaOH} \times \text{N of NaOH} \times 2.82}{\text{Weight of sample (g)}}$$

3.2.3.2.5. Total protein

The micro-Kjeldahl method as described in IS : 4079 (1967) was followed. Approximately 1 g accurately weighed ground sample, taken in a digestion flask, was added with 10 g potassium sulphate, 0.5 g mercuric oxide and 20 ml concentrated sulphuric acid (Sp. gr. 1.84, nitrogen-free). The flask was heated gently until frothing ceased, boiled briskly until the soution became clear, and then continued the boiling for about 1 h. The contents of the flask were cooled to room temperature and made up to volume in a 100 ml volumetric flask with distilled water. Ten ml of the aliquot of the solution was transferred to micro-Kjeldahl distillation flask and made the solution alkaline by 8 ml sodium hydroxide-sodium thiosulphate solution. The flask was immediately connected to a distillation apparatus and the tip of the condenser was immersed in a saturated solution of boric acid containing 2-3 drops of mixed indicator solution. The distillation was continued until about 50 ml of the distillate was collected which was then titrated against 0.02 N hydrochloric acid till violet colour appeared. A blank was carried out using all reagents except the test material.

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

Where

V_2 = ml of hydrochloric acid used in distillation,

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

N = normality of hydrochloric acid, and

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

3.2.3.2.6. Water-dispersible protein

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

3.2.3.2.7. Tyrosine value

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

3.2.3.2.8. Lactose and glucose-galactose

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

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

3.2.3.2.9. Lactic acid

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

3.2.3.2.10. pH

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

3.2.3.2.11. Titratable acidity

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

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

3.2.3.2.12. Ash

A ground sample (ca 3 g) was accurately weighed into a previously dried and weighed silica crucible and placed in a hot air oven at 100±1°C for 1 h. The dried sample was then ashed in a muffle furnace at 550±20°C for 3 h. The crucible was transferred directly to a dessicator, allowed to cool to room temperature and weighed immediately. the process of heating at 550±20°C for 30 min, cooling and weighing was repeated until the difference between two successive weighings was <1 mg. The lowest mass was recorded (IS : 1167 1965).

3.2.3.2.13. 2-Thiobarbituric acid

The method described by Keeney and Bassette (1959) was followed. One g of ground sample of churpi was reconstituted with 10 ml of distilled water in a 25 ml volumetric flask. One ml 40% trichloroacetic acid solution was added with gentle rotation. The flask was placed in a water bath at 70°C for 25 min and cooled immediately in ice bath. The contents were filtered through Whatman No. 42 filter paper. Eight ml of filtrate was transferred to a clean dry test tube and 2 ml of TBA reagent was added. The tubes were placed in 40°C water bath for 50 min and were cooled to room temperature. The absorbance was measured using a spectrophotometer at 425 nm.

3.2.3.2.14. 5-Hydroxymethylfurfural (HMF)

Free plus potential HMF were measured following the method as described by Keeney and Bassette (1959). One g of ground churpi was taken in a 50 ml test tube, 5 ml of 0.3 N oxalic acid was added in it and mixed thoroughly. The tube was covered with inverted 20 ml beaker and placed in boiling water bath for 1 h, after which it was removed and cooled with cold water to room temperature. This heating step was omitted while estimating the free HMF in the sample. Five ml 40% trichloroacetic acid was added in it, mixed and filtered through Whatman No. 42 paper. Four ml of the filtrate was taken into a test tube and 1.0 ml of 0.05 M 2-thiobarbituric acid was added. The tube was placed in a water bath at 40°C for 35 min, and then cooled to room temperature. The absorbance of the solution was measured at 443 nm against blank prepared same as sample, substituting water for churpi in the spectrophotometer. The following regression equations were obtained from the standard curves using standard HMF (Sigma, USA) solution.

$$\text{HMF } (\mu mol/g) = R \times 250.57 - 7.07$$
(for free HMF)

$$\text{HMF } (\mu mol/g) = R \times 183.67 - 3.06$$
(for total HMF)

where, R = absorbance

3.2.3.2.15. Para-dimethylaminobenzaldehyde reactivity

The method of Kumar and Hansen (1972) was followed. Two ml para-dimethylaminobenzaldehyde solution and 4 ml distilled formic acid were taken in screw capped test tubes. Ground sample (0.1 g) of churpi was added slowly into the reaction tube. The caps were closed and mixed thoroughly. Tubes were incubated at 37±1°C for 30 min and immediately cooled at 5°C. The cold contents were then centrifuged at 1000 x g for 10 min. Absorbance of the clear pink supernatant was recorded at 545 nm against a blank prepared from unheated milk. Data were expressed in terms of absorbance.

3.2.3.2.16. Energy value

The energy value of a sample determined by multiplying its per cent protein, fat and carbohydrate contents by the factors 4.1, 9.3, and 4.1 respectively, and adding all the multiplication values to get kcal (4.184cal = 1J) per 100 g (De 1980).

3.2.4. Sensory evaluation of churpi

The representative samples of market churpi procured from Bhutan, Sikkim and Darjeeling were served to a panel of seven judges. The judges were first trained in the assessment of quality attributes and the associated defects in churpi. The samples were presented to the panelist for sensory evaluation using a partially modified 100 point score card (Table 2) of Patil and Gupta (1986). The sensory texture was assessed using a rating scale (Table 3) in the form of a 14 cm horizontal dotted straight line with its left end indicating one parametric extreme (0) and the opposite end indicating the other extreme (100). Scoring was done by indicating the perceived intensity/acceptability by means of small vertical line along the 100 point scale.

3.2.5. Instrumental evaluation of churpi

Cubical (5 mm x 5 mm x 5 mm) samples of churpi were subjected to texture profile analysis using an Instron Universal testing

Table 2. Sensory score card for organoleptic evaluation of churpi

Attributes	Defects	Intensity			Samples			
		Slight	Difinite	Pronounced	A	B	C	D
Flavour (35)	High acid/sour	33	31	29				
	Bitter	25	18	5				
	Rancid	18	10	5				
	Oxidized	21	14	7				
	State	28	21	18				
	Mouldy/yeasty	18	7	0				
	Unclean	21	14	4				
	Fermented/fruity	18	10	4				
Body and texture (30)	Weak/soft	15	7	0				
	Mealy/grainy	24	18	12				
	Open	24	18	12				
	Soggy	0	0	0				
Gumminess and chewiness (25)	Rubbery	15	10	5				
	Brittle	12	6	2				
Colour and appearance (10)	Brown	6	4	2				
	Mouldy	0	0	0				
	Unnatural	2	0	0				
Total score (100)								

Date :

....

Signature of the Judge

Table 3. Unstructured scale for texture evaluation of churpi

To the panelist:

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

1. Elasticity

   Least elastic .... Extremely elastic

2. Firmness

   Too soft .... Too hard

3. Crumbliness

   Least crumbly .... Extremely crumbly

4. Smoothness

   Grainy/rough .... Extremely smooth

5. Gumminess

   Least gummy .... Extremely gummy

6. Chewiness

   Least chewy .... Extremely chewy

7. Overall textural quality

   Undesirable .... Most desirable

Remarks (if any):

Signature:

Date:

Name:

machine (Model 4301, Instron Limited, UK) fitted with a hundred N load cell and operated in a two bite compression mode with a crosshead speed of 50 mm/min and chart speed of 250 mm/min. All instron measurements with full scale deflection of strip chart recorder were carried out at 15°C. The parameters measured were hardness (maximum force recorded during the first compression cycle, N), cohesiveness (area under curve A_2/area under curve A_1), springiness (width of the downstroke in curve A_2, mm), gumminess (hardness x cohesiveness, N) and chewiness (gumminess x springiness, N.mm).

3.2.6. Preparation of laboratory samples

Based on the idea of traditional methods of its preparation, churpi was made in the laboratory.

3.2.6.1. Materials

3.2.6.1.1. Milk

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

3.2.6.1.2. Skim-milk powder

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

3.2.6.1.3. Coagulants

Citric acid (SD Chemicals, Bombay), lactic acid (SD Chemicals, Bombay) and tartaric acid (Glaxo laboratories, Bombay) were used as coagulants in desired concentrations.

3.2.6.2. Processing conditions

3.2.6.2.1. Standardization

Cow milk was separated by a mechanical cream separator (Kamdhenu, Sinhal Metal Industries, Bombay; capacity 60 l/h) (Fig.2). Skim milk obtained was standardized to desired fat and SNF levels by adding fresh cream and skim milk powder. Total solids content was determined with 5 g milk following the method as described in section 3.2.3.2.1. Fat in milk was determined by the Gerber method as described in SP : 18 (Part XI) (1981). Ten ml of sulphuric acid (density 1.807 - 1.812 g/ml at 27°C) was taken into a Gerber butyrometer for milk. A well-mixed sample (10.75 ml) of milk and 1 ml of amyl alcohol were added in it. The butyrometer was stoppered and the content was mixed by shaking at an angle of 45° until all the curd was dissolved. The butyrometer was kept in water bath at 65±2°C for 5 min. The butyrometer was then centrifuged at 1000 x g for 5 min and placed again in the water bath at 65±2°C for another 5 min. The fat content was directly read from the scale on the butyrometer. Titratable acidity of milk or whey was determined by titrating 10 ml of well-mixed sample against 0.1 N sodium hydroxide after adding 1 ml of 0.5% phenolphthalein indicator.

Fig. 2 A mechanical cream separator in operation

3.2.6.2.2. Heating of milk

Milk taken in a stainless steel container was heated to the desired temperature using a water bath.

3.2.6.2.3. Coagulation

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

3.2.6.2.4. Cooking

The coagulated mass, held in muslin cloth, was transferred to a stainless steel container and cooked with constant stirring to the desired level of moisture (Fig. 3) content using a water bath.

3.2.6.2.5. Pressing

The hot cooked mass wrapped in muslin cloth (Fig. 4) and transferred to a wooden hoop (10 cm x 10 cm x 10 cm) (Fig. 5) and pressed under desired dead weight (Fig. 6) for required time period.

3.2.6.2.6. Drying

The pressed mass was cut into four equal pieces hanged (Fig. 7) over wooden fire, and dried at 30$\pm$5°C for 40-50 days.

3.2.7. Optimization of process parameters

3.2.7.1. Fat level

Skim milk was standardized to 0.1, 1.0, 1.5 and 2.0% w/w fat and

Fig. 3. Cooking of green curd to a stringy mass

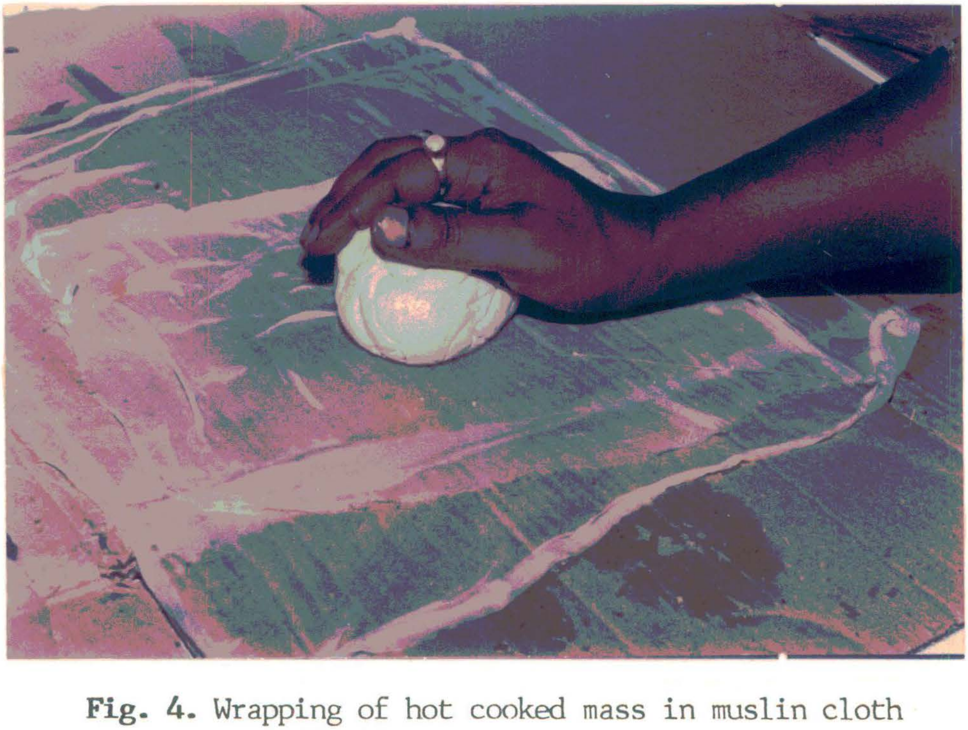

Fig. 4. Wrapping of hot cooked mass in muslin cloth

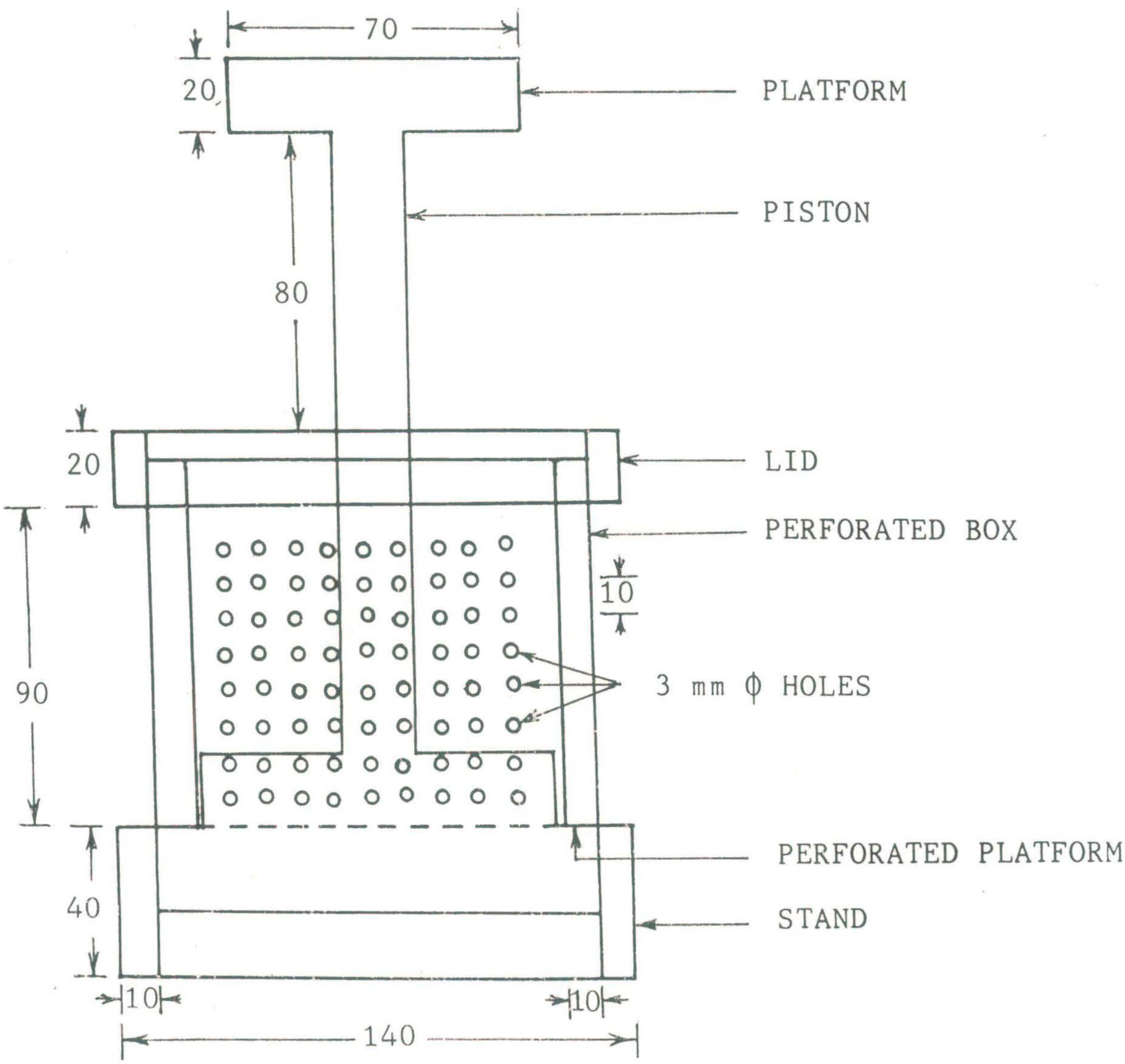

Fig. 5. The churpi press. (all dimensions are in mm)

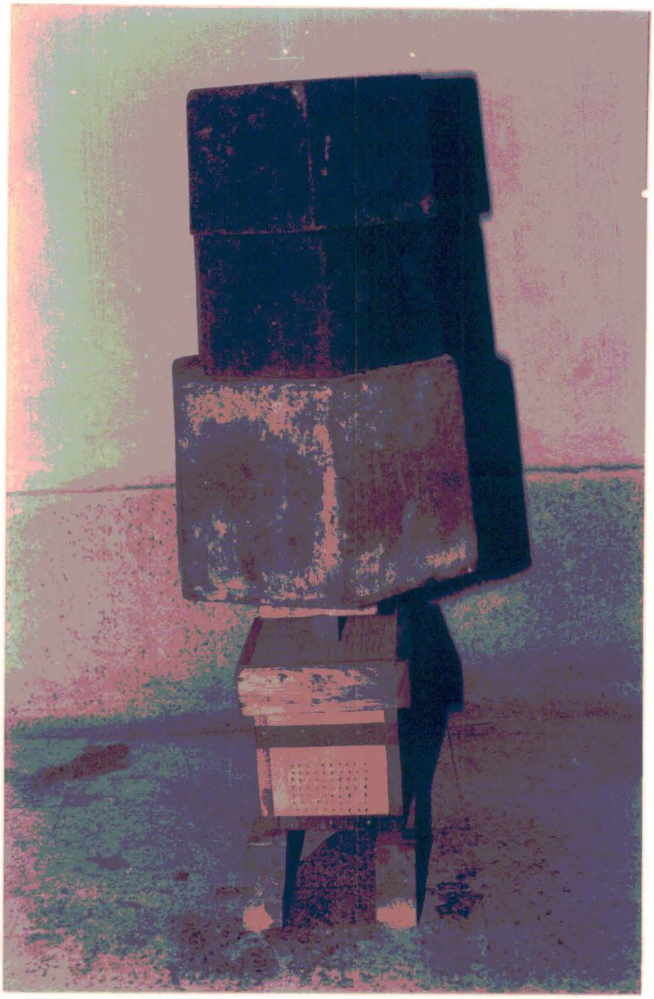

Fig. 6. Wrapped mass placed in a wooden hoop pressed under 90 kg dead weight

Fig. 7. Quarters of pressed mass hanging over wooden fire

8.7% w/w SNF using fresh cream and skim milk powder. Milk was heated to 70°C and the coagulation of milk was effected within 60 s using 2% w/v hot (70°C) citric acid solution. Whey was removed by straining through a muslin cloth without holding.The coagulated mass was cooked in a stainless steel container, using a boiling water bath, till the disappearance of free moisture followed by the appearance of an oily surface. The hot cooked coagulum was wrapped in a muslin cloth and pressed at 9 $kg.cm^{-2}$ pressure for 12 h. The pressed mass was cut into four equal cubical pieces and hanged over wooden fire (30±5°C) for 40-50 days. The churpi samples prepared from four different fat levels were subjected to various chemical, sensory and instrumental analyses.

3.2.7.2. Temperature of coagulation

Milk standardized to 1.0% w/w fat and 8.7% w/w SNF was heated to 40, 50, 60, 70 and 80°C and coagulated with 2.0% w/v citric acid solution. Rest of the procedure was same as described in section 3.2.7.1. Samples of churpi thus prepared were subjected to instrumental analysis. Total solids in whey, and per cent yield and moisture content of churpi were also determined.

3.2.7.3. Method of straining

Milk standardized to 1.0% w/w fat and 8.7% w/w SNF was heated to 70°C and coagulated at this temperature with hot (70°C) 2.0% w/v citric acid solution. The coagulum-whey mixture was held for 0, 5, 10 and 15 min before removing the whey by straining through a muslin cloth. The rest of the procedure was same as described in section 3.2.7.1. The samples of churpi thus prepared were subjected to instrumental analysis. Moisture content in chrupi, per cent yield of churpi, total solids in whey and total solids recovery were also determined.

3.2.7.4. Strength of citric acid

Milk standardized to 1.0% w/w fat and 8.7% w/w SNF was heated to 70°C and coagulated at this temperature with hot (70°C) 1.0, 2.0, and 3.0% w/v citric acid solution. Rest of the procedure was same as described in section 3.2.7.1. The samples of churpi thus prepared were subjected to instrumental analysis. Moisture content and per cent yield of churpi and total solids in whey were also determined.

3.2.7.5. Type of coagulant

Milk standardized to 1.0% w/w fat and 8.7% w/w SNF was heated to 70°C and coagulated with hot (70°C) 2.0% w/v lactic acid, 2.0% w/v citric acid, 1.5% w/v tartaric acid and 1.0% w/v citric acid in sour whey. After coagulation, the whey was strained immediately through a muslin cloth. The rest of the procedure for preparation of churpi was same as described in section 3.2.7.1. The samples of churpi thus prepared were subjected to sensory and instrumental analysis. Moisture content in churpi, per cent yield and total solids in whey were also determined.

3.2.7.6. Cooking of green curd

Milk standardized to 1.0% w/w fat and 8.7% w/w SNF was heated to 70°C and coagulated with 2.0% w/v citric acid solution (70°C) and strained immediately through a muslin cloth. In the first case of this standardizing procedure, the coagulum was not heated but pressed at 9 $kg.cm^{-2}$ pressure for 12 h and the pressed mass was hanged over wooden fire for drying. In subsequent cases, coagulum was heated in a stainless steel container by using boiling water bath for 5, 10, 15, 20 and 25 min. The hot coagulum was pressed at 9 $kg.cm^{-2}$ for 12 h, the pressed curd was cut into four equal pieces and allowed to dry over wooden fire. The moisture ratio was calculated by the formula

$$MR = \frac{\%\ moisture\ after\ cooking}{\%\ moisture\ before\ cooking}$$

The samples of churpi thus prepared were subjected to subjective and objective textural analysis and p-DMAB reactivity.

3.2.7.7. Pressing condition

Experiments were conducted at 7, 9 and 11 $kg.cm^{-2}$ pressures, and pressing time intervals of 2, 4, 6, 8, 10 and 12 h with the hot cooked mass as described in section 3.2.7.1. Moisture ratio at the onset of drying of the samples was determined as follows :

$$MR = \frac{\%moisture\ after\ pressing}{\%moisture\ before\ pressing}$$

Samples were analysed for instrumental parameters.

3.2.7.8. Drying behaviour as effected by size of churpi

Churpi prepared as described in section 3.2.7.1. was cut into different sizes (10 cm x 10 cm x 2.5 cm; 5 cm x 10 cm x 2.5 cm and 5 cm x 5 cm x 2.5 cm) which were dried under identical condition. The maximum and minimum drying temperatures and relative humidity at different days of drying were recorded.

3.2.8. Consumer response to laboratory-made churpi

Samples of churpi prepared under optimized conditions (Fig. 8) and the best quality market samples (Fig. 9) were served to (approximately 10 g of each sample) each of 200 consumers included in the study. Individuals, habituated in eating churpi, were randomly selected from among the staff of the institute. Score card used for this study is presented in Table 4.

Fig. 8. Churpi prepared under optimized conditions

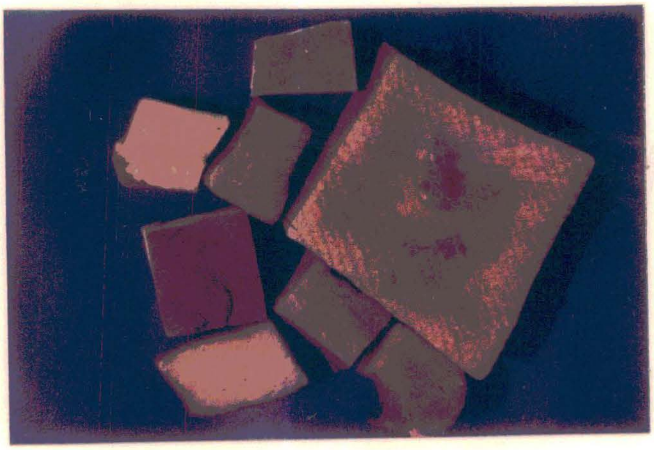

Fig. 9. Market churpi

Table 4. Score card for consumer survey of churpi

Name:

Age:

Sex: Male   Female

Please answer the following questions:

1. How often do you eat this product?
   - Several times a week __________
   - Several times a month __________
   - Several times a year or never __________

2. When do you eat this product?
   - With meal ______________
   - Between meals ___________
   - As and when desired ___________
   - On specific occasion __________
   - (please specify)

<u>Testing procedure</u>

You will receive two samples numbered "1" and "2". Taste both the samples and indicate your preference.

Preference: (Check only one of the following)

I prefer sample 1 over 2

- Extremely ______________
- Very much ______________
- Moderately ______________
- Slightly ______________

I prefer sample 2 over 1

- Extremely ______________
- Very much ______________
- Moderately ______________
- Slightly ______________

Reasons for preference: I prefer sample____ because

- It has better flavour____________
- It has better texture ____________
- It has better colour ____________
- It has better appearance __________
- Overall sensory quality is better __________

Signature

3.2.9. Changes in sensory attributes and physico-chemcal parameters during manufacturing churpi

Churpi was prepared under optimized process conditions. The observations were started immediately after removal of the pressed curd and proceeded at every 7 days interval till the desired quality of the product was reached. A sample of curd was prepared by mixing the representative portion of the product in a mortar and pestle. The mass was then subjected to various sensory and intrinsic chemical analyses.

3.2.10. Cost of churpi production

The cost of production of churpi was calculated for 100 l of cow milk per day. The factors included in the costing are the cost of raw material like milk, variable costs such as labour, fuel, testing, packaging, detergents, rent on building, depreciation on fixed costs, interest on capital investment, interest on variable costs and miscellaneous expenditure. The output of churpi in kg and the cost of surplus fat realized from standardization were taken into consideration.

3.2.11. Statistical analysis

Data on compositional parameters, sensory scores and subjective and objective textural properties were analysed using the randomized block design (Snedecor and Cochran 1967). The chemical, sensory and instrumental data were subjected to analysis on Wipro 386 Computer System in order to develop correlations and multivariate linear and log-linear (power function) relationship (Kapsalis and Moskowitz 1979; Moskowitz 1981) as follows:

$$S = k_0 + k_1 I_1 + k_2 I_2 + \ldots\ldots\ldots k_n I_n$$

$$S = K_o . I_1^{k_1} . I_2^{k_2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots I_n^{k_n}$$

where,

S = dependent variables, I_1, I_2 ....= independent variables, and k_o, k_1 .... are constants compounded from the data. Exponential relationships were described by the model $y = \exp(-k_1 x^{k_2})$, where k_1 and k_2 are constants and were determined by least square regression of experimental data (Raghavarao 1983). The model suggested by Page (1949) was used to express the rate of drying of churpi.

4. RESULTS

4.1. Survey on traditional methods of churpi preparation

Following the survey in Bhutan, Sikkim and Darjeeling, a detailed information was obtained on different traditional methods of preparation of churpi (Fig. 10). In the villages of extreme north of Bhutan, churpi is prepared from yak milk. Joo, a crossbred of yak (Bos mutus) and indigenous cow, is the common source of milk in the villages of North Sikkim. But in Darjeeling, cow milk is mostly used for its preparation. Traditionally, milk is defatted by bamboo churn (Fig.11), partly similar to mathani. Recently, they are being replaced by mechanical cream separators (Fig. 2). The methods of preparation of churpi in Bhutan are identical to those in Sikkim. But, in Darjeeling, the cooking step is omitted. The pressed green curd is cut into pieces and wrapped in hessian cloth and stitched before drying.

4.2. Analysis of market churpi

4.2.1. Chemical analysis

The proximate composition of churpi is presented in Table 5. The mean moisture content varied from 13.3 to 17.5% and differed ($P<0.05$) among the samples of different sources. The mean fat content ranged between 7.8 and 12.2%. The samples of Darjeeling had a higher ($P<0.05$) fat content than those of Bhutan and Sikkim. The mean protein content varied from 63.5 to 67.9%. The samples of Bhutan had a higher ($P<0.05$) content of protein than the samples of Darjeeling. Lactose, glucose-galactose, titratable acidity and pH of the samples of Bhutan differed ($P<0.05$) from the samples of Darjeling, but did not differ from those of Sikkim. Water-dispersible protein of the samples of all

Bhutan	Sikkim	Darjeeling
Yak milk	Joo milk	Cow/yak milk
↓	↓	↓
Defatted with bamboo churn	Defatted with bamboo churn	Defatted with bamboo churn
↓	↓	↓
Defatted milk warmed slightly	Defatted milk warmed slightly	Defatted milk warmed slightly
↓	↓	↓
Coagulated with previous batch of whey	Coagulated with previous batch of whey	Coagulated with previous batch of whey
↓	↓	↓
Removal of whey by filtering	Removal of whey by filtering	Removal of whey by filtering
↓	↓	↓
Cooking of green curd in a pan till the disappearance of free moisture	Cooking of green curd in a pan till the disappearance of free moisture	
↓	↓	
Hot cooked curd wrapped in hessian cloth and pressed heavily in a wooden box for overnight	Hot cooked curd wrapped in hessian cloth and pressed heavily in a wooden box for overnight	The green curd pressed heavily for 2–3 h, cut into pieces, wrapped in hessian cloth and stitched
↓	↓	↓
Pressed mass either cut into pieces or as such dried over wooden fire for 30-40 days	Pressed mass either cut into pieces or as such dried over wooden fire for 30-40 days	Dried over wooden fire for 30-40 days
↓	↓	↓
Cubical shaped churpi	Cubical shaped churpi	Cylindrical shaped churpi

Fig. 10. Traditional methods of preparation of churpi in three different places

Fig. 11. A bamboo churn traditionally used in churpi making

Table 5. Proximate composition of market churpi from three different sources

Constituents	Sources		
	Bhutan	Sikkim	Darjeeling
Moisture(%)	13.33^{c} (12.01-15.15)	15.26^{b} (12.97-16.08)	17.50^{a} (14.95-19.22)
Total fat(%)	7.78^{b} (6.33-9.79)	8.39^{b} (5.11-9.91)	12.25^{a} (9.85-14.82)
Free fat(%)	1.35^{b} (0.80-1.98)	1.95^{ab} (0.91-2.54)	2.77^{a} (1.85-4.00)
Total protein(%)	67.91^{a} (64.31-70.00)	65.28^{ab} (61.31-69.24)	63.49^{b} (60.00-65.04)
Water-dispersible protein(%)	4.04^{c} (3.67-4.45)	4.82^{b} (4.35-5.25)	7.32^{a} (6.55-8.00)
Lactose(%)	3.33^{a} (3.02-3.72)	3.40^{a} (3.01-3.65)	0
Glucose Galactose(%)	0.85^{a} (0.71-0.98)	0.91^{a} (0.52-1.16)	0.17^{b} (0-0.92)
Ash(%)	6.85^{a} (5.02-9.00)	6.78^{a} (5.02-7.51)	6.66^{a} (5.85-7.56)
Titratable acidity (as % lactic acid)	0.28^{a} (0.21-0.34)	0.33^{a} (0.28-0.37)	1.50^{b} (1.00-1.82)
pH	5.33^{a} (5.23-5.51)	5.25^{a} (5.20-5.33)	4.44^{b} (4.00-5.00)
Energy (MJ/100g)	0.087^{b} (0.084-0.095)	0.087^{b} (0.075-0.094)	0.090^{a} (0.081-0.097)

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

the three sources varied ($P<0.05$). Free fat content of the samples of Darjeeling was higher ($P<0.05$) than the samples of Bhutan. However, the samples of Bhutan and Sikkim and Sikkim and Darjeeling exhibited no difference ($P<0.05$) with respect to free fat content. Ash content of three different sources did not exhibit any difference ($P<0.05$). While the coefficients of variation for fat and protein content of the individual samples were as high as 29 and 16% respectively, the coefficients were 7% for moisture, 8% for lactose and 14% for ash content. Being higher in fat content, the samples of Darjeeling had higher ($P<0.05$) energy value than those of Bhutan and Sikkim.

Table 6 shows the intrinsic properties of market churpi. The contents of lactic acid, free fatty acid (FFA), 2-thiobarbituric acid (TBA) and tyrosine, and per cent reflectance of the samples of Darjeeling were higher ($P<0.05$) than the samples of two other sources. On the other hand, 5-hydroxymethylfurfural (HMF) and p-dimethylaminobenzaldehyde (p-DMAB) reactivity of the samples of Darjeeling were lower ($P<0.05$) than those of Bhutan and Sikkim. While free HMF content of the samples of Sikkim was higher ($P<0.05$) than the samples of Bhutan, the samples of Sikkim exhibited no difference ($P<0.05$) with the samples of Bhutan with respect to total HMF content.

4.2.2. Sensory analysis

The sensory scores of market churpi are presented in Table 7. The samples of Bhutan scored higher ($P<0.05$) compared to other two sources with respect to flavour, colour and appearance, gumminess and chewiness and total scores. However, there was no difference ($P<0.05$) in body and texture scores among the samples

Table 6. Intrinsic properties of market churpi from three different sources

Parameters	Sources		
	Bhutan	Sikkim	Darjeeling
Lactic acid (%)	0.03[b] (0.02-0.03)	0.03[b] (0.28-0.37)	0.25[a] (0.12-0.31)
Free fatty acid (%) (as oleic acid)	0.87[b] (0.81-0.96)	1.03[b] (0.89-1.20)	2.78[a] (1.25-4.23)
2-Thiobarbituric acid value (A_{425})	0.07[b] (0.05-0.09)	0.08[b] (0.06-0.09)	0.11[a] (0.08-0.15)
Tyrosine (mg/g)	0.15[b] (0.10-0.20)	0.16[b] (0.09-0.22)	0.45[a] (0.22-0.70)
Free HMF (µmol/g)	27.20[b] (22.20-32.11)	31.90[a] (28.26-34.21)	7.85[c] (4.10-14.73)
Total HMF (µmol/g)	60.99[a] (56.39-69.05)	66.18[a] (59.45-70.54)	30.77[b] (23.57-38.26)
P-DMAB reactivity (A_{545})	0.21[a] (0.17-0.25)	0.21[a] (0.16-0.30)	0.12[b] (0.09-0.15)
Reflectance (%)	31.88[b] (28.00-36.00)	25.60[c] (20.50-30.00)	44.28[a] (40.50-49.50)

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

Table 7. Sensory scores of market churpi from three different sources

Attributes	Sources		
	Bhutan	Sikkim	Darjeeling
Flavour	33.01[a]	29.60[b]	19.75[c]
	(30.0-34.0)	(26.0-33.0)	(13.0-25.0)
Body and texture	28.05[a]	25.75[a]	18.85[b]
	(27.0-29.0)	(23.0-28.0)	(13.0-22.0)
Colour and appearance	8.30[a]	6.80[b]	6.15[b]
	(8.0-9.0)	(5.0-7.0)	(5.0-8.0)
Gumminess and chewiness	23.45[a]	21.00[b]	17.45[c]
	(21.0-24.0)	(19.0-22.0)	(15.0-19.0)
Total score	92.80[a]	83.15[b]	62.20[c]
	(88.0-96.0)	(77.0-87.0)	(50.0-69.0)

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

of Bhutan and Sikkim. Samples of Darjeeling were criticized by the judges as rancid and brittle.

Churpi with high elasticity, firmness, smoothness, gumminess and chewiness, but low crumbliness was rated most desirable with respect to the overall textural quality. Samples of Darjeeling scored less ($P<0.05$) with respect to all the textural attributes, except crumbliness, than the samples of other two sources. Samples of Bhutan and Sikkim exhibited no difference ($P<0.05$), except for crumbliness and gumminess (Table 8).

4.2.3. Instrumental analysis

The instrumental textural properties of market churpi are shown in Table 9. Samples of Darjeeling had lower ($P<0.05$) values for all the instron parameters compared to the samples of two other sources. Differences ($P<0.05$) among the samples of Bhutan and Sikkim for all the instron parameters, except hardness and springiness, indicated the extent of textural variability of the market product. A typical texture profile curve for churpi is presented in Fig. 12.

4.2.4. Relationship between sensory attributes and intrinsic parameters

The coefficients of correlations between sensory attributes and intrinsic parameters of market churpi, and regression equations are presented in Tables 10 and 11, respectively. Free fatty acid and TBA values were found to bear a negative correlation ($P<0.001$) with flavour scores. Regression analysis indicates that FFA alone could explain 63% variation in flavour scores, and TBA showed a slightly lower effect (Table 11: equations 2,3). Lactic acid showed a negative correlation ($P<0.001$) and

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

Attributes	Sources		
	Bhutan	Sikkim	Darjeeling
Elasticity	77.60^{a} (60.00-90.00)	72.80^{a} (58.00-92.00)	36.95^{b} (26.00-52.00)
Firmness	76.90^{a} (70.00-90.00)	71.85^{a} (68.00-82.00)	42.70^{b} (39.00-52.00)
Crumbliness	19.30^{c} (7.00-38.00)	41.90^{b} (20.00-61.00)	74.50^{a} (59.00-85.00)
Smoothness	78.50^{a} (51.00-92.00)	63.30^{a} (43.00-84.00)	39.90^{b} (20.00-68.00)
Gumminess	82.35^{a} (61.00-92.00)	64.95^{b} (40.00-76.00)	30.95^{c} (7.00-51.00)
Chewiness	76.50^{a} (61.00-88.00)	69.95^{a} (59.00-85.00)	35.85^{b} (21.00-56.00)
Overall textural quality	77.50^{a} (61.00-89.00)	72.65^{a} (60.00-92.00)	36.95^{b} (26.00-50.00)

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

Table 9. Instron texture profile of market churpi from three different sources

Instron parameters	Sources		
	Bhutan	Sikkim	Darjeeling
Hardness (N)	993.70^{a} (930.80-1020.70)	916.63^{a} (815.70-996.50)	713.20^{b} (365.60-999.70)
Cohesiveness	0.60^{a} (0.40-0.84)	0.37^{b} (0.21-0.51)	0.16^{c} (0.08-0.29)
Springiness (mm)	0.76^{a} (0.50-0.90)	0.65^{ab} (0.50-0.80)	0.44^{b} (0.10-0.80)
Gumminess (N)	584.45^{a} (238.51-872.90)	336.33^{b} (209.26-476.64)	107.71^{c} (32.90-178.68)
Chewiness (N.mm)	442.06^{a} (190.81-698.32)	215.30^{b} (144.25-371.56)	50.99^{c} (8.40-142.95)

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

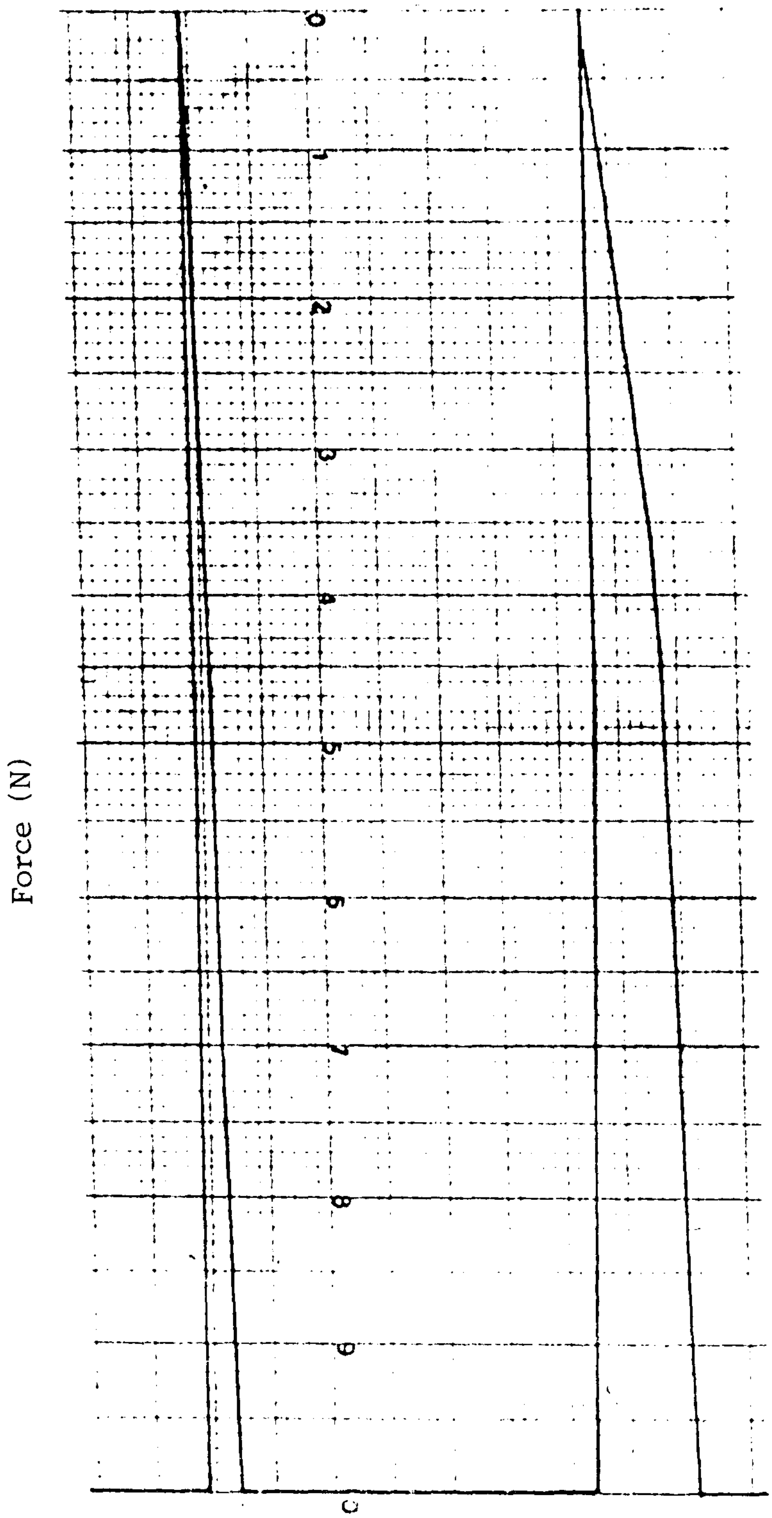

Fig. 12. Texture profile curve for churpi

Table 10. Coefficients of correlations* between sensory scores and intrinsic parameters of market churpi (58 d.f.)

Intrinsic parameters	Sensory attributes				
	Flavour	Body and texture	Colour and appearance	Gumminess and chewiness	Total score
Lactic acid	-0.842 (-0.860)	-0.773 (-0.812)	-0.506 (-0.537)	-0.789 (-0.803)	-0.848 (-0.891)
Total HMF	0.819 (0.790)	0.788 (0.766)	0.397** (0.413)**	0.719 (0.733)	0.829 (0.836)
Free HMF	0.854 (0.884)	0.810 (0.818)	0.445 (0.516)	0.729 (0.763)	0.854 (0.899)
Free fatty acid	-0.750 (-0.791)	-0.658 (-0.719)	-0.580 (-0.627)	-0.696 (-0.759)	-0.751 (-0.822)
2-Thibarbituric acid value	-0.771 (-0.737)	-0.783 (-0.752)	-0.542 (-0.550)	-0.734 (-0.719)	-0.809 (-0.796)
Tyrosine	-0.787 (-0.777)	-0.850 (-0.822)	-0.509 (-0.515)	-0.757 (-0.760)	-0.843 (-0.846)
P-DMAB reactivity	0.755 (0.771)	0.850 (0.822)	0.436 (0.477)	0.658 (0.659)	0.769 (0.799)

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

*Significant at $P<0.001$

**Significant at $P<0.01$

Table 11. Regression equations for sensory scores as related to intrinsic parameters of market churpi

Sl No.	Equations*	Coefficient of correlation (R)	Coefficient of determination (R^2)
1	$Fl = 11.11+0.310THMF$	0.819***	0.671
2	$Fl = 3.39FFA^{-0.381}$	0.791***	0.625
3	$Fl = 43.43-187.994TBA$	0.771***	0.594
4	$Fl = 34.86-29.279TY$	0.787***	0.620
5	$Fl = 2.631LA^{-0.229}$	0.859***	0.739
6	$Fl = 34.037-33.702LA-12.90TY$	0.871***	0.759
7	$Fl = 2.768LA^{-0.189}.FFA^{-0.083}$	0.864***	0.747
8	$Fl = 28.560-26.028LA+0.078THMF-10.543TY$	0.876***	0.767
9	$Fl = 37.92-28.563LA-0.953FFA-72.571TBA$	0.873***	0.762
10	$Fl = 30.17-21.422LA+0.063THMF-10.434TY-0.844FFA$	0.880***	0.774
11	$BT = 2.693LA^{-0.229}$	0.811***	0.659
12	$BT = 2.487FHMF^{0.234}$	0.818***	0.669
13	$BT = 1.521+0.422THMF$	0.766***	0.587
14	$BT = 29.85-22.257TY$	0.850***	0.722
15	$BT = 29.549-12.251LA-16.306TY$	0.871***	0.759
16	$BT = 26.30-7.705LA+0.046THMF-14.905TY$	0.875***	0.765
17	$BT = 23.25-3.381LA-14.696TY+21.298pDMAB+0.023THMF$	0.887***	0.786
18	$CA = 1.194THMF^{0.191}$	0.413**	0.170
19	$CA = 1.679LA^{0.093}$	0.537***	0.289
20	$CA = 2.424pDMAB^{0.273}$	0.476***	0.227
21	$CA = 2.234THMF^{0.034}.pDMAB^{0.239}$	0.478**	0.229
22	$CA = 2.406THMF^{-0.165}.pDMAB^{0.096}.LA^{-0.124}$	0.561**	0.315

Sl No.	Equations	Coefficient of correlation (R)	Coefficient of determination (R^2)
23	$GCh = 1.893 THMF^{0.288}$	0.729***	0.532
24	$GCh = 2.727 TY^{-0.186}$	0.760***	0.578
25	$GCh = 3.579 pDMAB^{0.319}$	0.659***	0.434
26	$GCh = 2.611 TY^{-0.099} . FHMF^{0.086}$	0.795***	0.632
27	$GCh = 2.297 TY^{-0.118} . THMF^{0.137}$	0.789***	0.623
28	$GCh = 23.512 - 13.281 LA - 6.207 TY$	0.824***	0.679
29	$GCh = 24.39 - 14.509 LA - 6.585 TY - 0.012 THMF$	0.825***	0.681
30	$TS = 3.892 LA^{-0.164}$	0.891***	0.794
31	$TS = 2.749 THMF^{0.412}$	0.836***	0.699
32	$TS = 4.435 FFA^{-0.274}$	0.822***	0.675
33	$TS = 3.954 TY$	0.846***	0.715
34	$TS = 3.584 LA^{-0.129} . THMF^{0.104}$	0.896***	0.804
35	$TS = 4.055 LA^{-0.077} . THMF^{0.025} . TY^{-0.106} . pDMAB^{0.103}$	0.919***	0.844
36	$TS = 3.971 LA^{-0.046} . FHMF^{0.084} . TY^{-0.088} . pDMAB^{0.071}$	0.924***	0.855

*Fl, Flavour
BT, Body and texture
CA, Colour and appearance
GCh, Gumminess and chewiness
LA, Lactic acid
FFA, Free faty acid
** Significant at P<0.01
*** Significant at P<0.001

TBA, 2-Thiobarbituric acid value
TY, Tyrosine value
FHMF, Free hydroxymethylfurfural
THMF, Total hydroxymethylfurfural
pDMAB, p-Dimethylaminobenzyldehyde reactivity
TS, Total score

explained 74% variation in flavour (Table 11: equation 5). Flavour of churpi was greatly dependent ($P<0.001$) on total HMF which explained 67% flavour variation (Table 11: equation 1). A cumulative effect of lactic acid and tyrosine accounted for 76% variation, and lactic acid and FFA reflected 75% variation in flavour (Table 11: equations 6,7). The four variables, lactic acid, FFA, tyrosine and total HMF were jointly responsible for 77% variation in flavour (Table 11: equation 10).

Hydroxymethylfurfural values and p-DMAB reactivities had a high positive correlation ($P<0.001$) with body and texture scores of market churpi. On the other hand, lactic acid, FFA,TBA and tyrosine contents were negatively correlated ($P<0.001$). Tyrosine contents alone explained 72% variation in body and texture scores, whereas total HMF showed a much lower effect (Table 11; equations 14,13). The combined effect of tyrosine and lactic acid gave better prediction for body and texture variation (Table 11:equation 15). Lactic acid and total HMF together with tyrosine content explained 77% variation but lactic acid, total HMF, tyrosine and p-DMAB jointly reflected 79% variation in body and texture scores of market churpi (Table 11: equations 16,17).

None of the intrinsic parameters predicted appreciably the colour and appearance scores, but the combined effect of total HMF, p-DMAB and lactic acid explained 32% of such variation (Table 11; equation 22).

Variation in gumminess and chewiness scores was better explained by free HMF than total HMF and tyrosine (Table 11: equations 26,23,24). The combined effect of lactic acid and tyrosine, and lactic acid, tyrosine and total HMF predicted 68% variation in gumminess and chewiness scores (Table 11: equations 28,29).

Lactic acid and total HMF jointly reflected 80% variation in total scores, whereas lactic acid alone predicted a slightly less per cent (Table 11: equations 30,34). Combination of lactic acid, free HMF, tyrosine and p-DMAB was perceivably better (86%) than the effect of any single parameter (Table 11: equation 36).

4.2.5. Relationship between chemical composition and instron parameters

The coefficients of correlation between different instron textural parameters and compositional characteristics of churpi and their regression equationsare presented in Tables 12 and 13, respectively. Instron hardness was highly correlated (P<0.001) with total solids. Water-dispersible protein showed a higher but negative correlation with hardness (P<0.001). Water-dispersible protein alone accounted for 54% variation in hardness, whereas total solids showed a much lower effect as shown in regression analysis (Table 13: equations 3,1). The combined effect of total solids and WDP was nearly same as that of total solids, WDP, free fat and titratable acidity (Table 13: equations 4,5).

Cohesiveness of churpi declined with increasing fat, titratable acidity, free fat and WDP, but total solids and total protein showed a high positive correlation (P<0.001) with cohesiveness. The regression analysis indicated that the individual contribution of total solids and WDP to cohesiveness was 57 and 78%, respectively (Table 13: equations 6,8), but the cumulative effect of total solids and WDP also explained the variation to the same extent of 78% (Table 13: equation 9). Total solids, titratable acidity, free fat and WDP jointly explained 79% variation in cohesiveness (Table 13: equation 11).

Table 12. Coefficients of correlations* between proximate composition and instron parameters of market churpi (58 d.f.)

Compositional variables	Instron parameters				
	Hardness	Cohesiveness	Springiness	Gumminess	Chewiness
Total solids	0.604 (0.584)	0.727 (0.757)	0.520 (0.514)	0.728 (0.756)	0.705 (0.723)
Total fat	-0.589 (-0.556)	-0.623 (-0.684)	-0.531 (-0.499)	-0.631 (-0.704)	-0.599 (-0.682)
Free fat	-0.496 (-0.455)	-0.613 (-0.611)	-0.394** (-0.369)**	-0.615 (-0.614)	-0.592 (-0.568)
Total protein	0.513 (0.474)	0.577 (0.596)	0.519 (0.452)	0.594 (0.606)	0.608 (0.596)
Water-dispersible protein	-0.736 (-0.700)	-0.807 (-0.883)	-0.563 (-0.598)	-0.813 (-0.891)	-0.786 (-0.861)
Titratable acidity	-0.684 (-0.689)	-0.731 (-0.857)	-0.648 (-0.626)	-0.742 (-0.877)	-0.704 (-0.840)

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

*Significant at $P<0.001$

**Significant at $P<0.01$

Table 13. Regression equations for instron texture profile parameters as related to composition of market churpi

Sl No.	Equations*	Coefficient of correlation (R)**	Coefficient of determination (R^2)
1	$H = -3511.01+51.835TS$	0.604	0.365
2	$H = 6.617TA^{-0.202}$	0.689	0.474
3	$H = 1324.37-83.398WDP$	0.736	0.541
4	$H = 1557.735-2.577TS-86.234WDP$	0.736	0.542
5	$H = 1561.13-2.573TS+1.346TA+17.676FF-93.734WDP$	0.738	0.545
6	$C = -94.276TS^{20.983}$	0.757	0.573
7	$C = 1.623TA^{-0.699}$	0.857	0.734
8	$C = 2.394WDP^{-2.151}$	0.883	0.779
9	$C = -2.74TS^{1.126}.WDP^{-2.067}$	0.883	0.780
10	$C = -19.161TS^{3.966}.TA^{-0.602}$	0.861	0.741
11	$C = -0.12TS^{0.342}.TA^{-0.179}.FF^{0.009}.WDP^{-1.620}$	0.886	0.785
12	$Spr = -4.15+0.056TS$	0.520	0.271
13	$Spr = -0.826.TA^{-0.375}$	0.598	0.358
14	$Spr = 1.11-0.092WDP$	0.648	0.419
15	$G = 112.869TS^{26.69}$	0.756	0.572
16	$G = 10.143WDP^{-2.766}$	0.891	0.795
17	$G = 4.967TA^{0.912}$	0.877	0.770
18	$G = 10.078F^{0.070}.WDP^{-2.82}$	0.891	0.795
19	$G = -8.068TS^{2.848}.TA^{-0.839}$	0.879	0.772
20	$G = 8.28TA^{-0.351}.WDP^{-1.779}$	0.889	0.807
21	$G = 8.198F^{0.082}.WDP^{-1.840}.TA^{-0.352}$	0.898	0.808
22	$G = 2.229TS^{0.419}.WDP^{-2.735}$	0.891	0.785
23	$G = 13.654TS^{-1.202}.TA^{-0.367}.FF^{-0.018}.WDP^{-1.804}$	0.899	0.808

Sl No.	Equations	Coefficient of correlation (R)	Coefficient of determination (R^2)
24	$Ch = -162.042TS^{37.641}$	0.723	0.523
25	$Ch = 11.504WDP^{-3.939}$	0.861	0.741
26	$Ch = 4.141TA^{-1.287}$	0.840	0.706
27	$Ch = 14.601TS^{-0.679}.WDP^{-0.399}$	0.861	0.741
28	$Ch = 20.756TS^{-2.519}.WDP^{-2.939}.TA^{-0.422}$	0.866	0.749
29	$Ch = 19.604TS^{-2.184}.WDP^{-3.183}.FF^{0.144}.TA^{-0.384}$	0.866	0.751

* H, Hardness
C, Cohesiveness
Spr, Springiness
G, Gumminess
Ch, Chewiness

TS, Total solids
TA, Titratable acidity
F, Total fat
FF, Free fat
WDP, Water-dispersible protein

** Significant at P<0.001

Springiness was found to be negatively correlated with fat, free fat, WDP and titratable acidity, but showed a positive correlation ($P<0.001$) with total solids and total protein (Table 12).

Gumminess and chewiness of churpi were greatly dependent on total solids and WDP. The correlation coefficients were higher for log-model (Table 12). Gumminess and chewiness tended to decline with increasing WDP. This alone explained 80% variation in gumminess and 74% in chewiness (Table 13: equations 22,27). Total solids, titratable acidity, free fat and WDP were jointly responsible for 81% variation in gumminess and 75% in chewiness.

4.2.6. Relationship between sensory textural descriptors and instron texture profile

Correlations between sensory texture descriptors and instrumental texture profile of churpi as well as the regression equations are presented in Tables 14 and 15, respectively. Sensory firmness was correlated ($P<0.001$) with instron hardness. But, instron hardness reflected only 39% sensory firmness (Table 15: equation 1). Table 14 shows that instron hardness also exhibited correlation ($P<0.001$) with all other sensory texture descriptors. Regression analysis indicates that hardness could account for 40% crumbliness, 46% smoothness, 34% sensory gumminess, 56% sensory chewiness and 56% overall textural quality (Table 15: equations 12,18,19,23,28).

Cohesiveness of churpi also had a correlation ($P<0.001$) with all the sensory descriptors. Cohesiveness alone could express 60% firmness, i.e. much better than that predicted hardness alone (Table 15: equations 2,1). Cohesiveness also explained 66%

Table 14. Coefficients of correlations* between sensory texture descriptors and instron texture profile parameters of market churpi (58 d.f.)

	Sensory texture descriptors						
Instron parameters	Firmness	Crumbliness	Elasticity	Smoothness	Gumminess	Chewiness	Overall textural quality
Hardness	0.624 (0.579)	-0.635 (-0.537)	0.724 (0.751)	0.668 (0.679)	0.582 (0.448)	0.741 (0.750)	0.724 (0.750)
Cohesiveness	0.734 (0.777)	-0.753 (-0.723)	0.718 (0.789)	0.717 (0.689)	0.813 (0.763)	0.751 (0.798)	0.723 (0.791)
Springiness	0.465 (0.418)	-0.571 (-0.470)	0.610 (0.637)	0.588 (0.591)	0.540 (0.413)**	0.591 (0.603)	0.607 (0.635)
Gumminess	0.739 (0.778)	-0.763 (-0.724)	0.726 (0.829)	0.730 (0.724)	0.816 (0.740)	0.755 (0.836)	0.730 (0.831)
Chewiness	0.688 (0.699)	-0.752 (-0.683)	0.670 (0.823)	0.733 (0.733)	0.793 (0.670)	0.748 (0.813)	0.701 (0.823)

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

*Significant at $P<0.001$

**Significant at $P<0.01$

Table 15. Regression equations between sensory texture descriptors and instron text profile of market churpi

Sl No.	Equations*	Coefficient of correlation (R)**	Coefficient determinatio (R^2)
1	$Fr = 8.51+0.063H$	0.62	0.39
2	$Fr = 4.545C^{0.370}$	0.78	0.60
3	$Fr = 2.492G^{0.291}$	0.78	0.61
4	$Fr = 3.229Ch^{0.177}$	0.70	0.49
5	$Fr = 40.90+37.356Spr$	0.47	0.22
6	$Fr = 3.463H^{0.154}.C^{0.334}$	0.78	0.61
7	$Fr = 0.958H^{0.508}.C^{0.326}.Spr^{-0.181}$	0.79	0.63
8	$El = 0.283H^{0.699}.C^{0.322}$	0.85	0.72
9	$El = -0.312H^{0.706}.C^{0.324}.Ch^{-0.002}$	0.85	0.72
10	$El = -0.527H^{0.734}.C^{0.321}.Spr^{-0.018}$	0.85	0.72
11	$El = -0.635H^{0.668}.C^{0.237}.Ch^{-0.022}.G^{0.103}$	0.85	0.72
12	$Cr = 129.49-0.096H$	0.64	0.40
13	$Cr = 87.31-68.584Spr$	0.57	0.33
14	$Cr = 74.23-0.084G$	0.76	0.58
15	$Cr = 68.94-0.100Ch$	0.75	0.57
16	$Cr = 124.872-0.081H-14.782Spr$	0.64	0.41
17	$Cr = 104.04-0.028H-69.107C-13.657Spr$	0.79	0.62
18	$Sm = -3.931H^{1.180}$	0.68	0.46
19	$SG = -14.21+0.084H$	0.58	0.34
20	$SG = 24.95+92.195C$	0.81	0.66
21	$SG = 29.86+0.086G$	0.82	0.67
22	$SG = 16.85+0.001H+82.55C+18.416Spr$	0.83	0.68
23	$SCh = -4.855H^{1.317}$	0.75	0.56

Sl No.	Equations*	Coefficient of correlation (R)**	Coefficient of determination (R^2)
24	$SCh = 4.325 Spr^{0.495}$	0.60	0.36
25	$SCh = 2.672 Ch^{0.274}$	0.81	0.66
26	$SCh = -7.427 H^{1.682} . Spr^{-0.195}$	0.76	0.58
27	$SCh = -2.142 H^{0.861} . C^{0.333} . Spr^{-0.136}$	0.86	0.73
28	$OTQ = -4.631 H^{1.288}$	0.75	0.56
29	$OTQ = 4.633 C^{0.488}$	0.79	0.63
30	$OTQ = -0.242 H^{0.694} . C^{0.323}$	0.85	0.72
31	$OTQ = 2.144 G^{0.243} . Ch^{0.114}$	0.84	0.70
32	$OTQ = 1.861 C^{-0.046} . G^{0.295} . Ch^{0.102}$	0.84	0.70
33	$OTQ = -0.667 H^{0.673} . C^{0.245} . Spr^{13.298} . G^{183.397} . Ch^{-183.315}$	0.85	0.72

* Fr, Firmness
El, Elasticity
Cr, Crumbliness
Sm, Smoothness
SG, Sensory gumminess
SCh, Sensory Chewiness
OTQ, Overall textural quality

H, Hardness
C, Cohesiveness
G, Gumminess
Ch, Chewiness
Spr, Springiness

** Significant at $P<0.001$

sensory gumminess (Table 15: equation 20).

Springiness of churpi was negatively correlated ($P<0.001$) with crumbliness, but positively correlated ($P<0.001$) with other sensory descriptors. Springiness alone could predict only 33% crumbliness (Table 15: equation 13). But, it, together with hardness, accounted for 41% of this texture descriptor of churpi (Table 15: equation 16) and for 62% when combined with both hardness and cohesiveness (Table 15: equation 17). Similarly, springiness alone explained only 22% firmness (Table 15: equation 5), whereas in combination with hardness and cohesiveness it could predict 63% of firmness (Table 15: equation 7).

Combination of hardness, cohesiveness and springiness predicted 72% elasticity (Table 15: equation 10). Significant ($P<0.001$) correlation of instrumental springiness and sensory elasticity was also observed (Table 14).

Instron gumminess, a product of hardness and cohesiveness, and instron chewiness, a product of gumminess and springiness, showed better correlation than those shown by hardness with all sensory descriptors. Thus, gumminess and chewiness accounted for 61 and 49% firmness, and 58 and 57% crumbliness, respectively (Table 15: equations 3,4,14,15). Instron gumminess was correlated ($P<0.001$) with sensory gumminess and the corresponding regression equation predicted 67% variation in sensory gumminess as explained by instron gumminess (Table 15: equation 21). Instrumental chewiness was also correlated ($P<0.001$) with sensory chewiness and could express 66% variation (Table 15: equation 25). Furthermore, sensory chewiness could appreciably be better predicted by instron hardness, cohesiveness and springiness taken together (Table equation 27).

Instron hardness coupled with cohesiveness explained 72% and the combination of instrumental gumminess and chewiness accounted for 70% of the overall sensory texture score of churpi (Table 15: equations 30,31), whereas as high as 72% of the same could be explained by all the instron texture profile parameters taken together (Table 15: equation 33).

4.3. Optimization of process parameters in the manufacture of churpi

4.3.1. Fat level in milk

The influence of different fat levels in cow milk on the sensory attributes of churpi is shown in Table 16. Churpi prepared from milk of 1.0% fat scored higher ($P<0.01$) with respect to each sensory attribute, except gumminess and chewiness, than the samples prepared from milk at other fat levels. It had the desired body , smooth texture and characteristic flavour. Churpi prepared from skim milk (0.1% fat) was placed at intermediate sensory scale. But, these samples were criticized as having flat flavour and course texture. Excessive gumminess and chewiness of these samples were not liked by the judges. Churpi prepared from milk of more than 1.0% fat had a low ($P<0.01$) score with respect to all sensory attributes, and was criticized as having rancid flavour and weak body.

Instrumental analysis of churpi prepared from milk of differentiat levels (Table 17) showed that all the instrumental parameters, except gumminess, of churpi prepared from milk of 0.1% fat had higher ($P<0.01$) scores than the samples prepared

Table 16. Effect of fat content of milk on sensory attributes of churpi

Attributes	Fat content in milk (%)			
	0.1	1.0	1.5	2.0
Flavour	27.25^{b} (26.14-28.28)	33.25^{a} (32.14-34.14)	22.18^{c} (21.57-23.14)	16.36^{d} (15.14-17.43)
Body and texture	25.78^{b} (24.85-26.28)	28.25^{a} (27.43-29.14)	19.28^{c} (18.28-20.43)	19.25^{c} (17.85-20.14)
Colour and appearance	7.00^{c} (6.71-7.28)	8.61^{a} (8.14-9.28)	7.60^{b} (7.14-8.14)	7.60^{b} (7.14-8.14)
Gumminess and chewiness	24.25^{a} (23.14-25.14)	23.28^{b} (23.14-24.28)	14.86^{d} (14.28-15.43)	15.14^{c} (14.28-16.14)
Total score	86.77^{b} (83.56-93.42)	93.49^{a} (92.28-94.84)	63.92^{c} (62.27-65.56)	58.34^{d} (57.70-58.98)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.01$).

Table 17. Effect of fat content of milk on instron texture profile of churpi

Instron parameters	Fat content in milk (%)			
	0.1	1.0	1.5	2.0
Hardness (N)	1118.95[a] (1090.16-1150.15)	999.80[b] (994.40-1010.00)	961.58[bc] (957.49-965.83)	875.40[c] (749.80-957.10)
Cohesiveness	0.92[a] (0.91-0.96)	0.76[b] (0.70-0.83)	0.40[c] (0.38-0.41)	0.16[d] (0.15-0.19)
Springiness (mm)	0.75[a] (0.70-0.80)	0.66[b] (0.60-0.80)	0.75[a] (0.70-0.80)	0.93[c] (0.80-1.00)
Gumminess (N)	788.38[a] (700.10-879.30)	760.12[a] (696.08-838.30)	383.58[b] (373.42-395.99)	141.03[c] (110.28-171.89)
Chewiness (N.mm)	592.36[a] (540.18-625.36)	502.92[b] (417.65-597.90)	286.09[c] (261.39-316.79)	128.94[d] (110.28-142.14)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.01$).

from milk of 1.0, 1.5 and 2.0% fat levels. The mean gumminess score of churpi prepared from milk of 0.1% fat was, however, higher than the samples prepared from 1.0% fat in milk.

Table 18 indicates the chemical composition of churpi as influenced by different fat levels in milk. The moisture content in churpi varied almost inversely with fat level in milk. The fat content in churpi increased wilth the increase in fat level of milk, while the protein, carbohydrate and ash contents correspondingly decreased. While free fat, FFA and TBA values increased ($P<0.01$) with the increase in fat level of milk, titratable acidity did not bear any definite relationship with the fat level of milk.

4.3.2. Temperature of coagulation of milk

Standardized milk was heated to different temperatures ranging from 40-80°C and coagulated immediately at that temperature with 2% w/v citric acid of the same temperature. Instrumental texture profile of churpi prepared from milk coagulated at different temperatures is presented in Table 19. The samples of churpi prepared by coagulating at 70°C had a higher ($P<0.05$) cohesiveness, gumminess and chewiness compared to those prepared by coagulating milk at other temperatures. Samples of churpi prepared by coagulating milk at 60 and 70°C had no ($P<0.05$) effect on instrumental hardness. Churpi prepared by coagulating milk at 50°C has less ($P<0.05$) cohesiveness but higher ($P<0.05$) springiness compared to the samples prepared at four other coagulation temperatures.

Moisture content in churpi and total solids in whey decreased consistently with an increase in temperature of coagulation of milk (Table 20). On the other hand, yield and

Table 18. Effect of fat content of milk on chemical composition of churpi

Constituents	Fat content in milk (%)			
	0.1	1.0	1.5	2.0
Moisture (%)	15.00[a] (14.91-15.09)	13.04[b] (12.98-13.09)	11.28[c] (11.02-11.98)	11.30[c] (11.27-11.32)
Total fat (%)	0.70[d] (0.66-0.74)	7.74[c] (7.64-7.80)	12.03[b] (11.98-12.08)	16.03[a] (15.96-16.10)
Total protein (%)	72.00[a] (71.62-72.31)	68.49[b] (68.44-68.56)	66.30[c] (66.24-66.36)	62.15[d] (62.07-62.22)
Lactose (%)	3.74[a] (3.71-3.89)	3.11[b] (3.07-3.20)	3.03[bc] (3.01-3.05)	2.97[c] (2.95-2.98)
Glucose-galactose (%)	1.01[a] (0.92-1.08)	0.76[b] (0.74-0.78)	0.75[b] (0.74-0.76)	0.74[b] (0.73-0.75)
Ash (%)	7.56[a] (7.24-7.96)	6.96[b] (6.92-6.99)	6.90[b] (6.89-6.91)	6.87[b] (6.85-6.88)
Free fat (%)	0.14[d] (0.12-0.16)	1.40[c] (1.38-1.42)	2.19[b] (2.16-2.22)	2.97[a] (2.96-2.98)
Titratable acidity (as % lactic acid)	0.30[a] (0.29-0.31)	0.28[a] (0.26-0.30)	0.28[a] (0.26-0.30)	0.29[a] (0.27-0.30)
Free fatty acid (as % oleic acid)	0.58[d] (0.57-0.59)	0.86[c] (0.84-0.88)	1.06[b] (1.01-1.09)	1.50[a] (1.49-1.51)
2-Thiobarbituric acid value	0.03[d] (0.02-0.04)	0.06[c] (0.04-0.07)	0.10[b] (0.09-0.11)	0.13[a] (0.12-0.14)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.01$).

Table 19. Effect of temperature of coagulation of milk on instron texture profile of churpi

Instron parameters	Coagulation temperature (°C)				
	40	50	60	70	80
Hardness (N)	458.90^{d} (450.37-470.85)	557.23^{c} (550.30-564.30)	976.75^{a} (925.00-996.00)	999.80^{a} (994.40-1010.00)	886.50^{b} (884.00-890.40)
Cohesiveness	0.26^{bc} (0.23-0.30)	0.19^{c} (0.17-0.22)	0.23^{bc} (0.20-0.25)	0.76^{a} (0.70-0.83)	0.30^{b} (0.29-0.31)
Springiness (mm)	1.25^{b} (1.00-1.40)	1.60^{a} (1.40-1.80)	1.08^{b} (1.00-1.20)	0.66^{c} (0.60-0.80)	1.20^{b} (1.20-1.20)
Gumminess (N)	120.60^{c} (104.15-141.25)	105.88^{c} (93.55-121.90)	222.02^{b} (198.16-248.80)	760.12^{a} (696.08-838.30)	261.52^{b} (247.86-274.04)
Chewiness (N.mm)	152.66^{c} (104.15-197.76)	168.72^{c} (150.10-195.04)	238.60^{bc} (198.16-266.40)	502.92^{a} (417.65-597.90)	313.82^{b} (297.43-328.85)

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

Table 20. Effect of temperature of coagulation of milk on yield and solids recovery of churpi

Attributes	Coagulation temperature (°C)				
	40	50	60	70	80
Moisture (%)	13.80[a]	13.72[a]	13.45[b]	13.02[c]	12.95[c]
	(13.77-13.83)	(13.69-13.75)	(13.42-13.47)	(12.96-13.09)	(12.93-12.97)
Yield (%)	3.40[c]	3.52[c]	3.88[b]	4.13[a]	4.27[a]
	(3.32-3.47)	(3.45-3.59)	(3.81-3.96)	(4.08-4.17)	(4.22-4.32)
Total solids recovery (%)	30.20[d]	31.30[d]	34.65[c]	37.00[b]	38.34[a]
	(29.56-30.83)	(30.67-31.94)	(34.01-35.29)	(36.53-37.45)	(37.91-38.76)
Total solids in whey (%)	7.78[a]	7.65[a]	7.60[a]	7.54[ab]	7.30[b]
	(7.67-7.87)	(7.61-7.71)	(7.57-7.65)	(7.48-7.59)	(7.01-7.42)

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

total solids recovery increased with the increase in temperature of coagulation.

4.3.3. Method of straining

Milk standardized to 1.0% fat and 8.7% SNF was heated to 70°C and coagulated with hot (70°C) 2.0% w/v citric acid solution. The coagulated mass was left in whey for 0, 5, 10 and 15 min before straining. The instrumental texture profiles of churpi, thus prepared, are presented in Table 21. Samples of churpi prepared by straining immediately after coagulation had higher ($P<0.05$) hardness, cohesiveness, gumminess and chewiness but less ($P<0.05$) springiness than the samples prepared by three other methods. Samples of churpi prepared from the coagulated mass held in whey for 5 and 10 min showed no difference ($P<0.05$) with respect to hardness, cohesiveness, springiness and chewiness. Hardness of churpi prepared from the coagulated mass held in whey for 15 min was less ($P<0.05$) compared to the samples of three other holding periods. However, there was no difference ($P<0.05$) in cohesiveness, springiness, gumminess and chewiness with the samples prepared by 10 min holding in whey.

The results for moisture, yield, total solids in whey and total solids recovery are presented in Table 22. Moisture content in churpi had definite relationship with the period of holding the coagulated mass in whey. But there was no ($P<0.05$) variation in the samples of churpi prepared from the coagulated mass, held in whey for 0 and 5 min. Due to higher ($P<0.05$) moisture content and less total solids in whey, the yield of churpi prepared from the coagulated mass held in whey for 15 min was higher ($P<0.05$) than the samples of three other holding periods.

Table 21. Effect of method of straining on instron texture profile of churpi

Instron Parameters	Holding time in whey (min)			
	0	5	10	15
Hardness (N)	999.80[a] (994.40-1010.00)	991.74[b] (990.60-992.70)	900.80[b] (900.30-901.40)	892.44[c] (890.10-894.15)
Cohesiveness	0.76[a] (0.70-0.83)	0.37[b] (0.33-0.39)	0.32[b] (0.29-0.34)	0.34[b] (0.32-0.36)
Springiness (mm)	0.66[c] (0.60-0.80)	0.90[b] (0.80-1.00)	0.93[ab] (0.85-1.00)	1.00[a] (1.00-1.00)
Gumminess (N)	760.12[a] (696.08-838.30)	362.00[b] (326.90-386.96)	288.28[c] (261.26-306.10)	301.22[c] (284.83-321.89)
Chewiness (N.mm)	502.92[a] (417.65-597.90)	326.28[b] (285.90-376.75)	266.66[b] (235.13-297.46)	301.22[b] (284.83-321.89)

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

Table 22. Effect of method of straining on yield and solids recovery of churpi

	Holding time in whey (min)			
Attributes	0	5	10	15
Moisture (%)	13.02^{c} (12.96-13.09)	13.02^{c} (12.96-13.08)	13.43^{b} (13.38-13.46)	13.66^{a} (13.62-13.69)
Yield (%)	4.13^{c} (4.08-4.17)	4.13^{c} (4.08-4.20)	4.27^{b} (4.22-4.32)	4.47^{a} (4.37-4.54)
Total solids in whey (%)	7.54^{a} (7.48-7.59)	7.52^{a} (7.49-7.58)	7.33^{b} (7.26-7.37)	7.19^{c} (7.14-7.24)
Total solids recovery (%)	37.00^{c} (36.53-37.45)	37.00^{c} (36.54-37.68)	38.12^{b} (37.71-38.54)	39.81^{a} (38.90-40.39)

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

4.3.4. Strength of citric acid

The instrumental texture profile of churpi prepared by using 1.0, 2.0 and 3.0% w/v citric acid solution are presented in Table 23. The mean hardness of churpi increased with the increase in concentration of solution. Cohesiveness, gumminess and chewiness of churpi prepared by using 2% solution were higher (P<0.05) than the samples prepared by 1.0 and 3.0% solution.

The moisture, yield and total solids recovery of churpi varied inversely with the concentration of the solution (Table 24).

4.3.5. Type of coagulant

The effects of different coagulants, viz. lactic acid, citric acid, citric acid in sour whey and tartaric acid on sensory attributes, instrumental texture profile, moisture retention, yield, total solids recovery and total solids loss in whey were studied. Sensory attributes as effected by different coagulants are shown in Table 25. There was no flavour difference (P<0.05) among the samples made from lactic and citric acid, but the samples of citric acid in sour whey and tartaric acid scored less (P<0.05) compared to those produced by using two other coagulants. Similar to flavour, there was no difference (P<0.05) in body and texture of the samples prepared from lactic and citric acid solution, but the samples prepared from tartaric acid scored less (P<0.05) than those prepared from three other coagulants. Colour and appearance of the samples prepared from lactic and citric acid did not differ (P<0.05). However, samples of churpi prepared from two other coagulants showed a variation

Table 23. Effect of strength of citric acid on instron texture profile of churpi

Instron parameters	Citric acid (% w/v)		
	1.0	2.0	3.0
Hardness (N)	984.43[a] (975.30-993.80)	999.80[a] (994.40-1010.00)	1006.25[a] (996.80-1015.20)
Cohesiveness	0.39[a] (0.35-0.46)	0.76[b] (0.70-0.83)	0.57[c] (0.55-0.59)
Springiness (mm)	0.92[a] (0.80-1.00)	0.66[b] (0.60-0.80)	0.64[c] (0.60-0.70)
Gumminess (N)	381.28[a] (341.91-448.64)	760.12[b] (696.08-838.30)	571.01[c] (550.00-588.11)
Chewiness (N.mm)	349.18[a] (341.91-358.91)	502.92[b] (417.65-597.90)	363.59[a] (340.37-385.00)

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

Table 24. Effect of strength of citric acid solution on yield and solids recovery of churpi

Strength (%)	Citric acid pH	Citric acid Titratable acidity (%)	Citric acid Amount used (ml/100 ml milk)	Moisture (%)	Yield (%)	Total solids recovery (%)	Total solids in whey (%)
1.0	2.51 (2.50-2.52)	1.47 (1.42-1.50)	21.50 (20.80-22.00)	13.61[a] (13.54-13.66)	4.25[a] (4.02-4.30)	37.83[a] (37.43-38.24)	7.34[c] (7.29-7.39)
2.0	2.25 (2.18-2.30)	2.69 (2.66-2.72)	12.06 (11.50-13.00)	13.04[b] (13.02-13.09)	4.13[b] (4.08-4.17)	37.00[b] (36.53-37.45)	7.54[b] (7.48-7.59)
3.0	2.02 (1.97-2.06)	3.99 (3.90-4.00)	10.47 (10.00-11.00)	12.80[c] (12.77-12.83)	3.93[c] (3.86-4.00)	35.35[c] (34.70-35.99)	7.64[a] (7.56-7.72)

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

Table 25. Effect of different coagulants on the sensory scores of churpi

Sensory attributes	Coagulants			
	Lactic acid (2.0% w/v)	Citric acid (2.0% w/v)	Citric acid (1% w/v) in sour whey	Tartaric acid (1.5% w/v)
Flavour	33.68[a] (32.85-34.57)	33.35[a] (32.14-34.14)	30.28[b] (29.43-31.28)	25.14[c] (24.85-25.43)
Body and texture	28.07[a] (27.43-28.57)	28.25[a] (27.43-29.14)	26.36[b] (25.57-27.14)	22.00[c] (21.71-22.28)
Colour and appearance	8.28[a] (7.71-8.85)	8.61[a] (8.14-9.28)	7.39[b] (6.85-7.85)	6.50[c] (6.28-6.71)
Gumminess and chewiness	24.14[a] (23.28-25.14)	23.28[b] (22.57-24.28)	21.50[c] (20.85-22.14)	15.00[d] (14.71-15.28)
Total scores	94.16[a] (92.42-95.41)	93.49[a] (92.28-94.84)	85.51[b] (82.70-88.41)	68.63[c] (67.69-69.56)

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

(P<0.05). Churpi made of lactic acid solution was with higher (P<0.05) gumminess and chewiness than the samples made of other coagulants. On the other hand, samples of churpi prepared with tartaric acid solution scored less (P<0.05) compared to other coagulants. There was no variation (P<0.05) in total scores of the samples of churpi prepared from lactic acid and citric acid solution. Churpi samples made using tartaric acid solution had less (P<0.05) score compared to the samples prepared from three other coagulants.

Instrumental texture profile of churpi as effected by different coagulants is presented in Table 26. No difference (P<0.05) in hardness of churpi was observed among the samples prepared from lactic acid, citric acid and citric acid in sour whey solution. However, samples prepared from tartaric acid showed less (P<0.05) hardness compared to the samples prepared from other coagulants. There was no variation (P<0.05) in cohesiveness among the samples prepared from lactic and citric acid solution. Springiness of the samples prepared from citric acid in sour whey solution was higher (P<0.05) than the samples of other coagulants. Samples of churpi prepared from tartaric acid solution showed less (P<0.05) gumminess and chewiness compared to the samples prepared from three other coagulants. No difference (P<0.05) was observed in gumminess among the samples of churpi prepared from lactic and citric acid solution. However, chewiness of the samples of churpi prepared from lactic acid solution was higher (P<0.05) than the samples prepared from three other coagulants.

The results for moisture, yield, total solids recovery and total solids loss in whey are presented Table 27. The mean pH

Table 26. Effect of different coagulants on instron texture profile of churpi

Instron parameters	Coagulants			
	Lactic acid (2.0% w/v)	Citric acid (2.0% w/v)	Citric acid (1.0% w/v) in sour whey	Tartaric acid (1.5% w/v)
Hardness (N)	997.08^{a} (991.70-1006.00)	999.80^{a} (994.40-1010.00)	989.23^{a} (990.60-990.60)	883.61^{b} (879.40-888.15)
Cohesiveness	0.75^{a} (0.70-0.79)	0.76^{a} (0.70-0.83)	0.25^{b} (0.24-0.25)	0.15^{c} (0.14-0.15)
Springiness (mm)	0.78^{c} (0.75-0.80)	0.66^{d} (0.60-0.80)	1.13^{a} (1.01-1.20)	1.00^{b} (0.95-1.01)
Gumminess (N)	745.40^{a} (694.19-786.84)	760.12^{a} (696.08-838.30)	242.36^{b} (236.30-247.63)	128.12^{c} (123.11-132.84)
Chewiness (N.mm)	576.93^{a} (555.35-590.13)	502.92^{b} (417.65-597.90)	272.83^{c} (236.30-296.76)	126.58^{d} (116.96-132.84)

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

Table 27. Effect of different coagulants on the quality, yield and solids recovery of churpi

Coagulants								
Name	% w/v	pH	Titratable acidity (%)	Amount (ml/100 ml milk)	Moisture (%)	Yield (%)	Total solids recovery (%)	Total solids in whey (%)
Lactic acid	2.0	2.26 (2.24-2.28)	1.45 (1.40-1.48)	13.93 (13.80-14.00)	13.65[a] (13.58-13.70)	4.73[a] (4.70-4.76)	42.06[a] (42.00-42.10)	7.06[a] (7.00-7.15)
Citric acid	2.0	2.25 (2.18-2.30)	2.69 (2.66-2.72)	12.06 (11.50-13.00)	13.04[b] (12.98-13.09)	4.13[b] (4.08-4.17)	37.00[b] (36.53-37.45)	7.54[b] (7.48-7.59)
Citric acid in sour whey	1.0	2.97 (2.94-3.00)	2.40 (2.38-2.42)	14.06 (14.00-14.20)	13.04[b] (12.99-13.09)	4.36[c] (4.32-4.38)	38.47[c] (36.99-39.02)	7.30[c] (7.28-7.32)
Tartaric acid	1.5	2.07 (2.06-2.08)	2.10 (2.06-2.12)	11.83 (11.80-11.90)	12.84[c] (12.79-12.87)	3.97[d] (3.92-4.00)	35.76[d] (35.72-35.82)	7.57[d] (7.54-7.60)

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

and titratable acidity of various coagulants ranged from 2.07-2.97 and 1.45-2.69%, respectively. The greatest drop in pH was in tartaric acid solution followed by citric acid, lactic acid and citric acid in sour whey solution. The mean amount of coagulant used varied from 11.83-14.08 ml/100 ml milk. The moisture content of the samples of churpi prepared from lactic acid solution was higher ($P<0.05$) than the samples prepared from three other coagulants. The mean yield of churpi ranged from 3.97-4.73% depending upon the moisture retention and total solids recovery in churpi. The yield of churpi prepared from lactic acid was higher ($P<0.05$) than the yield of the samples prepared from three other coagulants. Consequently, the total solids recovery in churpi prepared from lactic acid was also higher ($P<0.05$) than the samples prepared from three other coagulants.

4.3.6. Cooking of green curd

Since the initial moisture content of different samples was observed to differ ($P<0.05$) from each other, the ratio of moisture content at time t (m_t) to initial moisture content (m_o), i.e. m_t/m_o, was used to arrive at the uniformity of data. Figure 13 shows the effect of cooking time on moisture ratio. The trend of moisture variation was nearly exponential and is represented by the equation $MR = \exp(-0.018t^{1.099})$.

Figure 14 shows the effect of elasticity on moisture ratio at different intervals of cooking. The graph was parabolic whose axis was vertical and only a small segment of such a parabola appeared in the process of fitting. The fitted second degree polynomial equation is represented by $MR = 2.097 - 0.039El + 0.003El^2$.

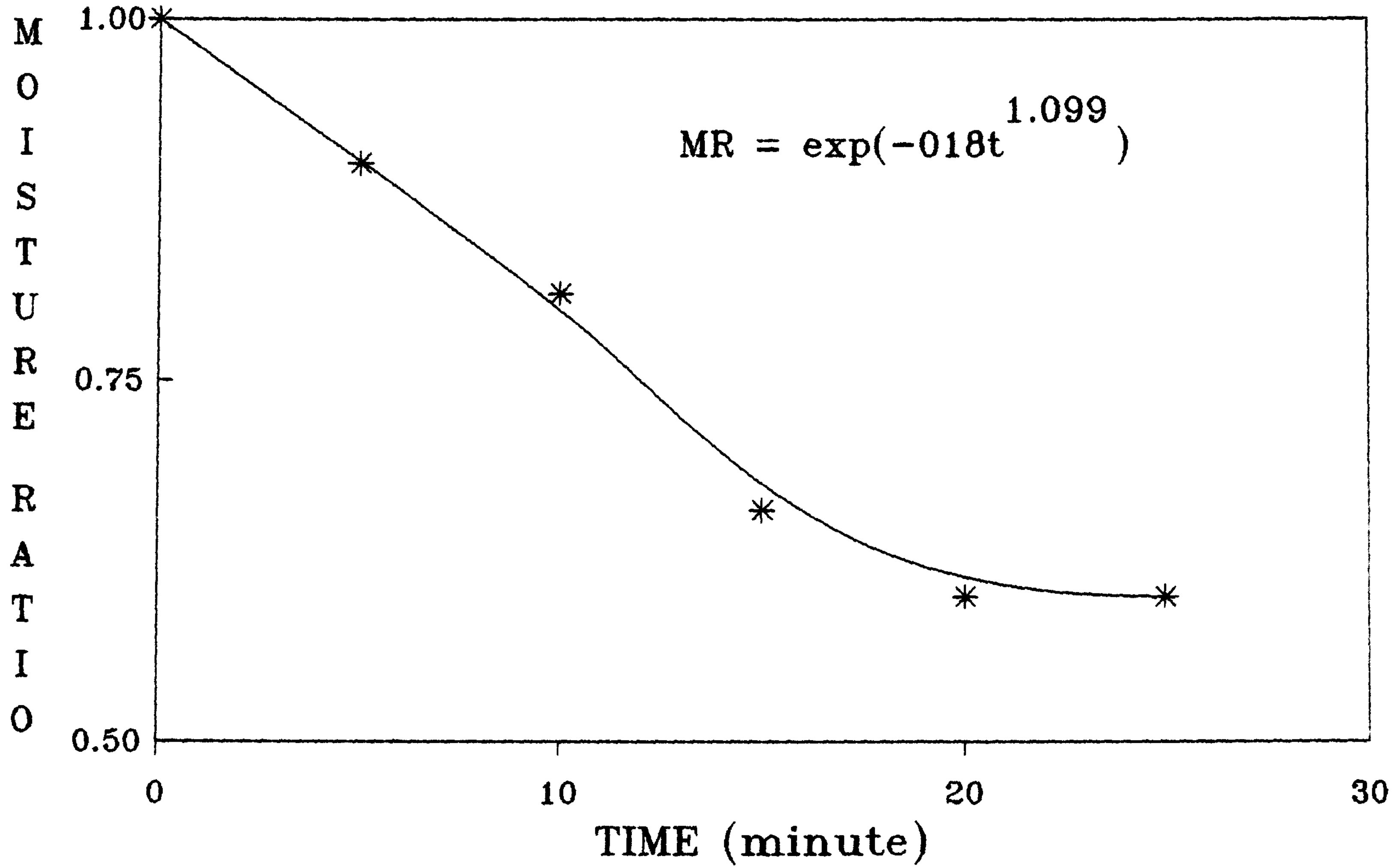

Fig. 13. Effect of time of cooking on moisture ratio (MR)

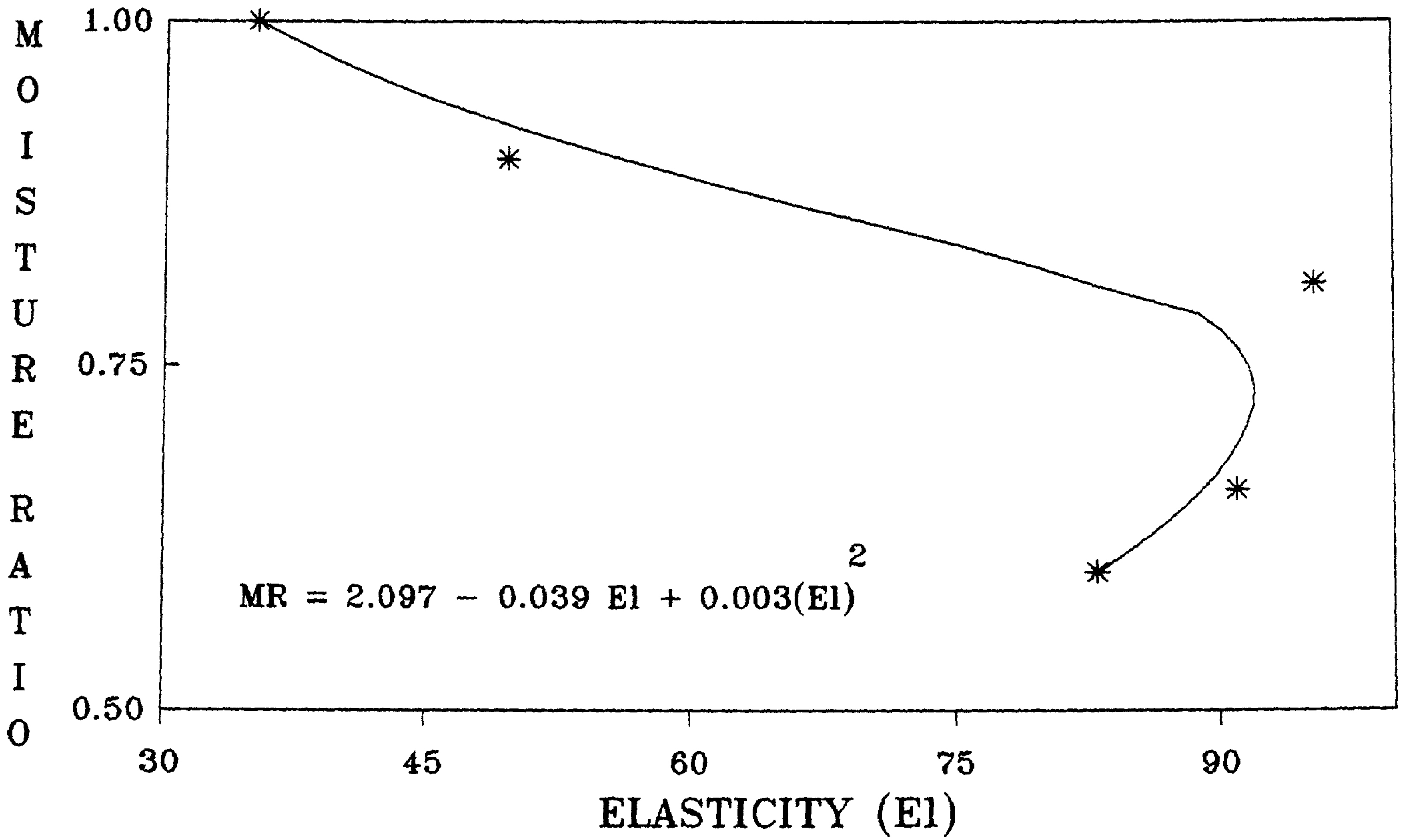

Fig. 14.Effect of elasicity(El) on moisture ratio(MR) at different interval of cooking

Effect of instrumental springiness on moisture ratio at different intervals of cooking is shown in Fig. 15 and represented by the equation of second degree polynomial $MR = 1.63 - 2.228Spr + 1.151Spr^2$.

Relationship of p-DMAB reactivity with instrumental hardness and cohesiveness are presented in Figs 16 and 17, respectively. Hardness and cohesiveness were highly correlated ($P<0.001$) with p-DMAB reactivity. Sensory firmness, smoothness and crumbliness were also correlated ($P<0.001$) with p-DMAB reactivity and are presented in Figs 18, 19 and 20, respectively.

4.3.7. Pressing condition

Since initial moisture content of different samples differed ($P<0.05$) from each other, the moisture ratio was used to arrive at uniformity of data. Figure 21 shows the effect of pressing time on moisture ratio at different pressures. The trend of moisture variation was nearly exponential. As the quantum of pressure was increased, initial rate of moisture ratio reduction was greater. The moisture ratio can be correlated to pressing time by a relationship of the form, $MR = \exp(-k_1 t^{k_2})$, where k_1 and k_2 are pressure dependent constants, which were determined by least square regression of the experimental data after log transformation at different pressures. The variation of k_1 and k_2 with pressure is represented in Fig. 22. Constants k_1 and k_2 were related to pressure according to the following equation:

$$k_1 = 0.0014 \exp(0.409p)$$

$$k_2 = 6.112 \exp(-0.214p)$$

Hence, the unified model for moisture content may be represented by the following equation:

$$MR = \exp\{-0.0014 \exp(0.409p)\}\ t^{\{6.112 \exp(-0.214p)\}}$$

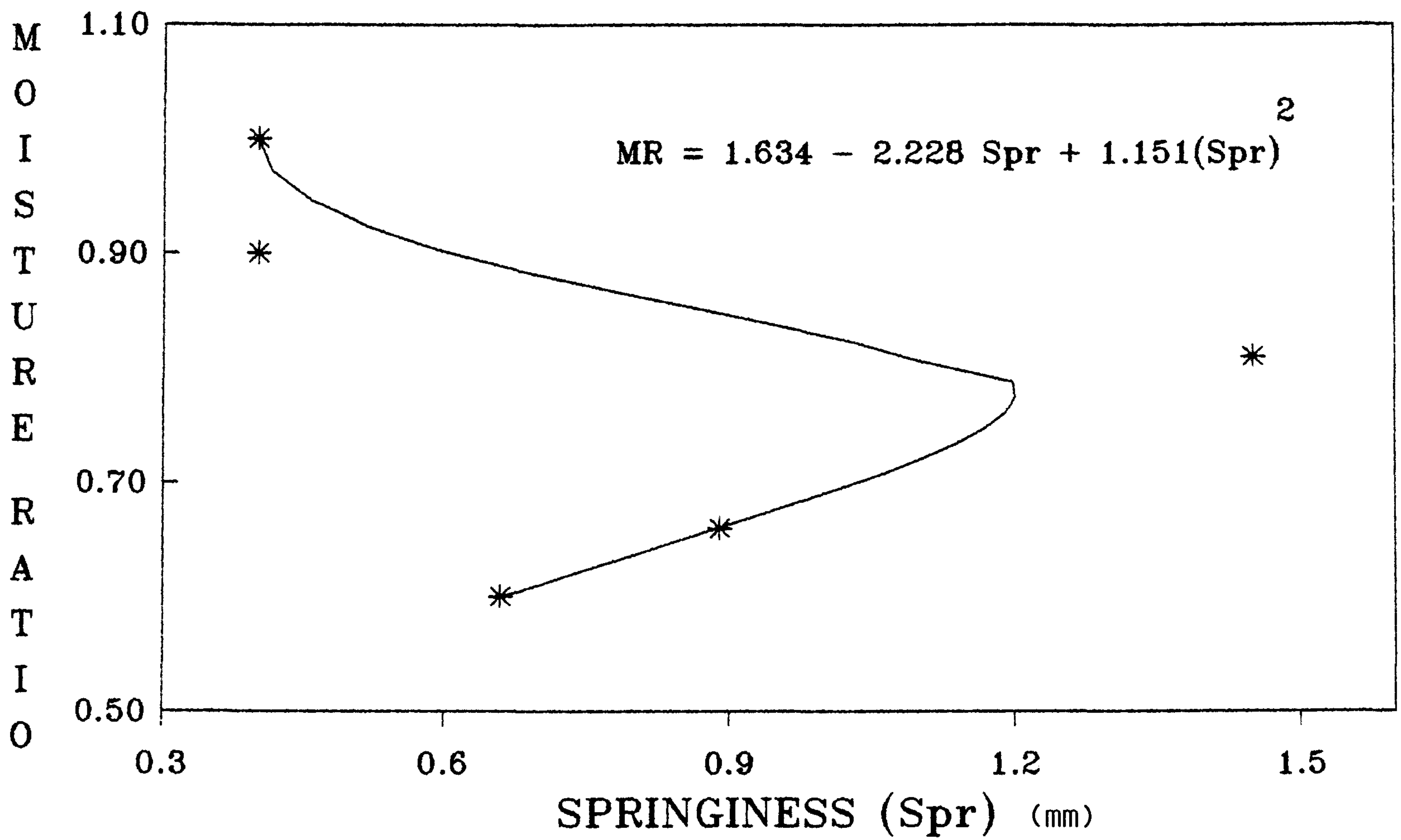

Fig. 15 . Effect of springiness(Spr) on moisture ratio(MR) at different interval of cooking

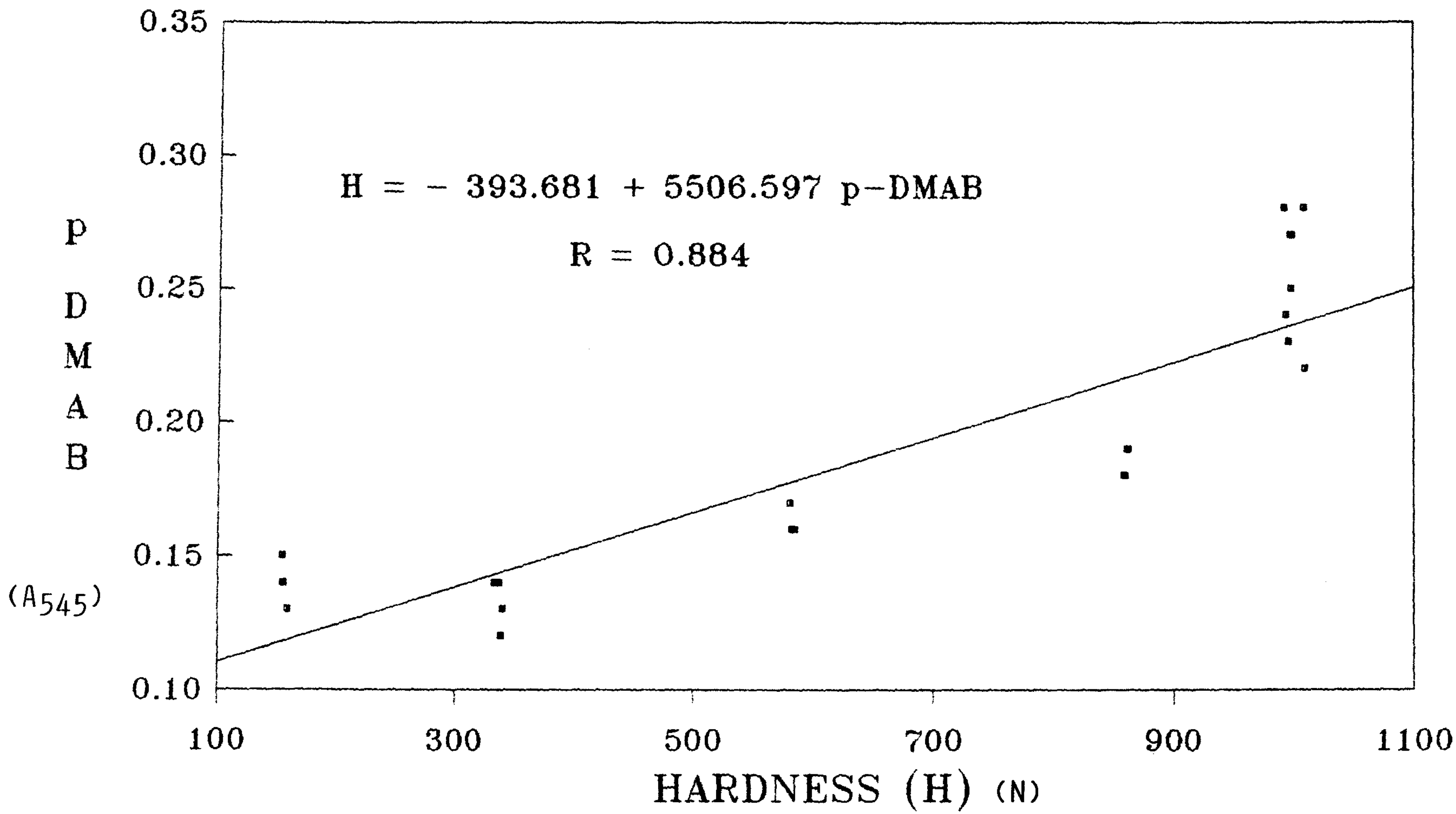

Fig. 16 . Relationship between hardness(H) and p-DMAB reactivity at different interval of cooking

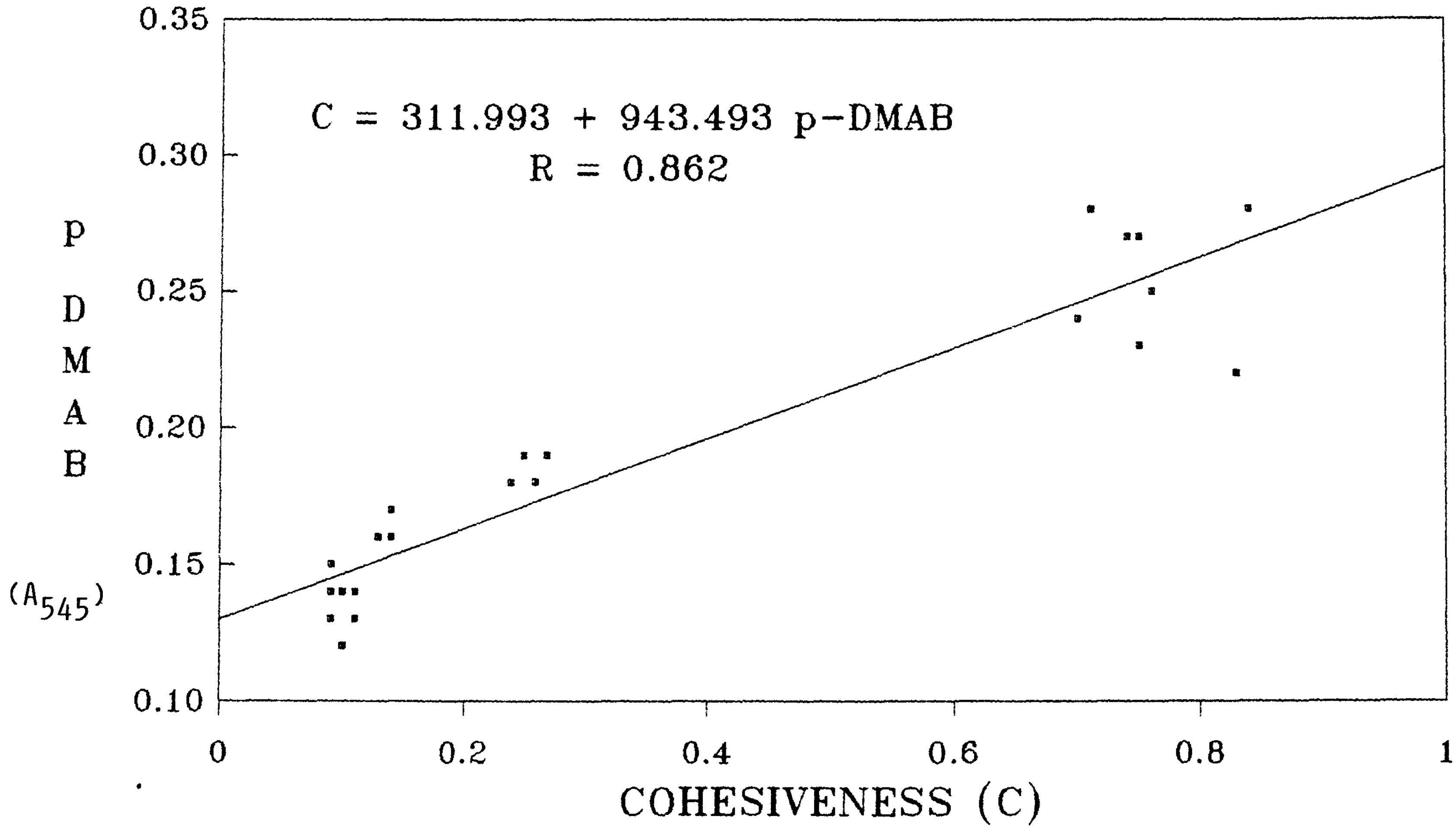

Fig. 17 .Relationship between cohesiveness(C) and p-DMAB reactivity at different interval of cooking

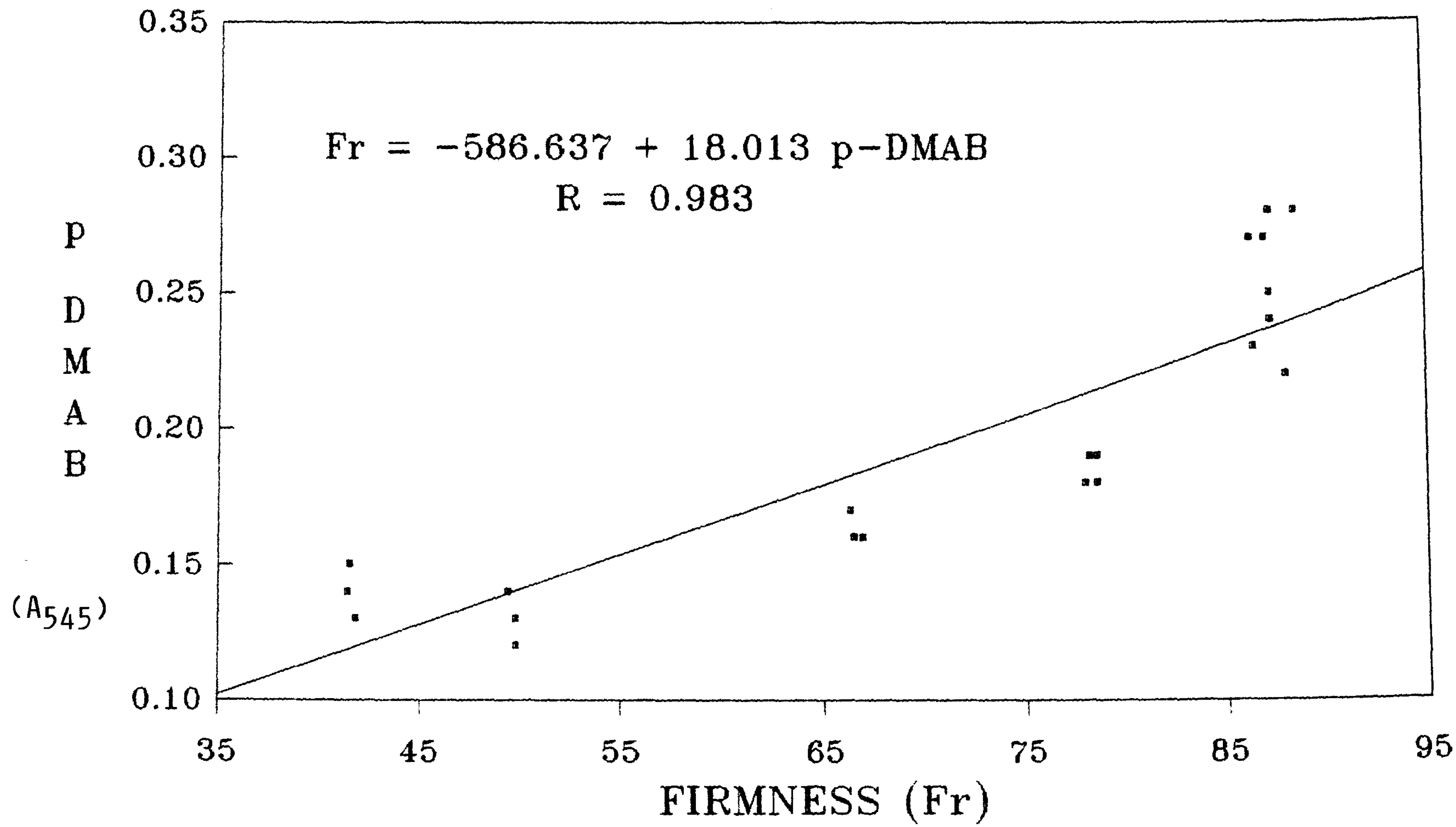

Fig. 18 . Relationship between firmness (Fr) and p−DMAB reactivity at different interval of cooking

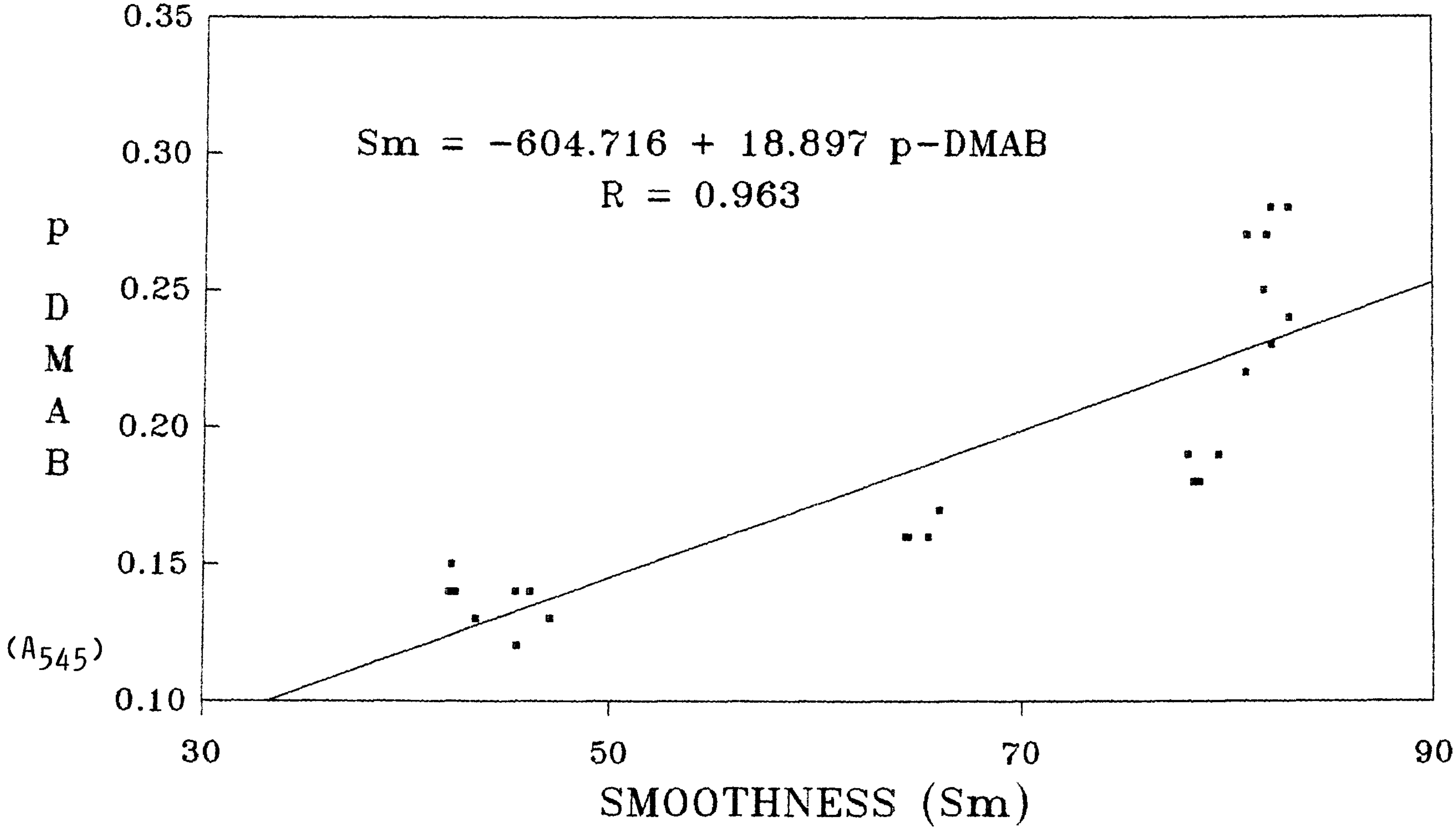

Fig. 19 . Relationship between smoothness(Sm) and p−DMAB reactivity at different interval of cooking

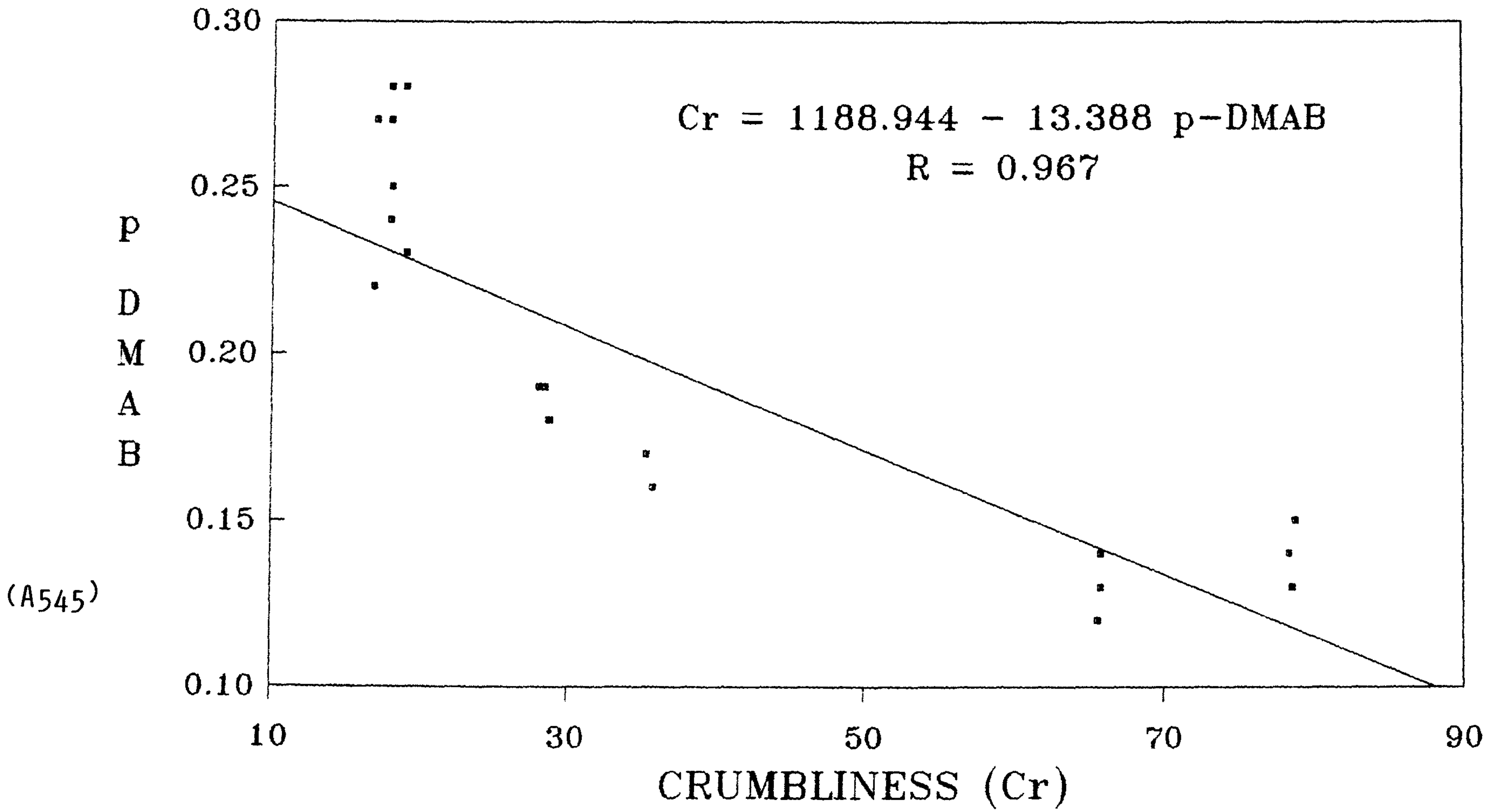

Fig. 20. Relationship between crumbliness(Cr) and p-DMAB reactivity at different interval of cooking

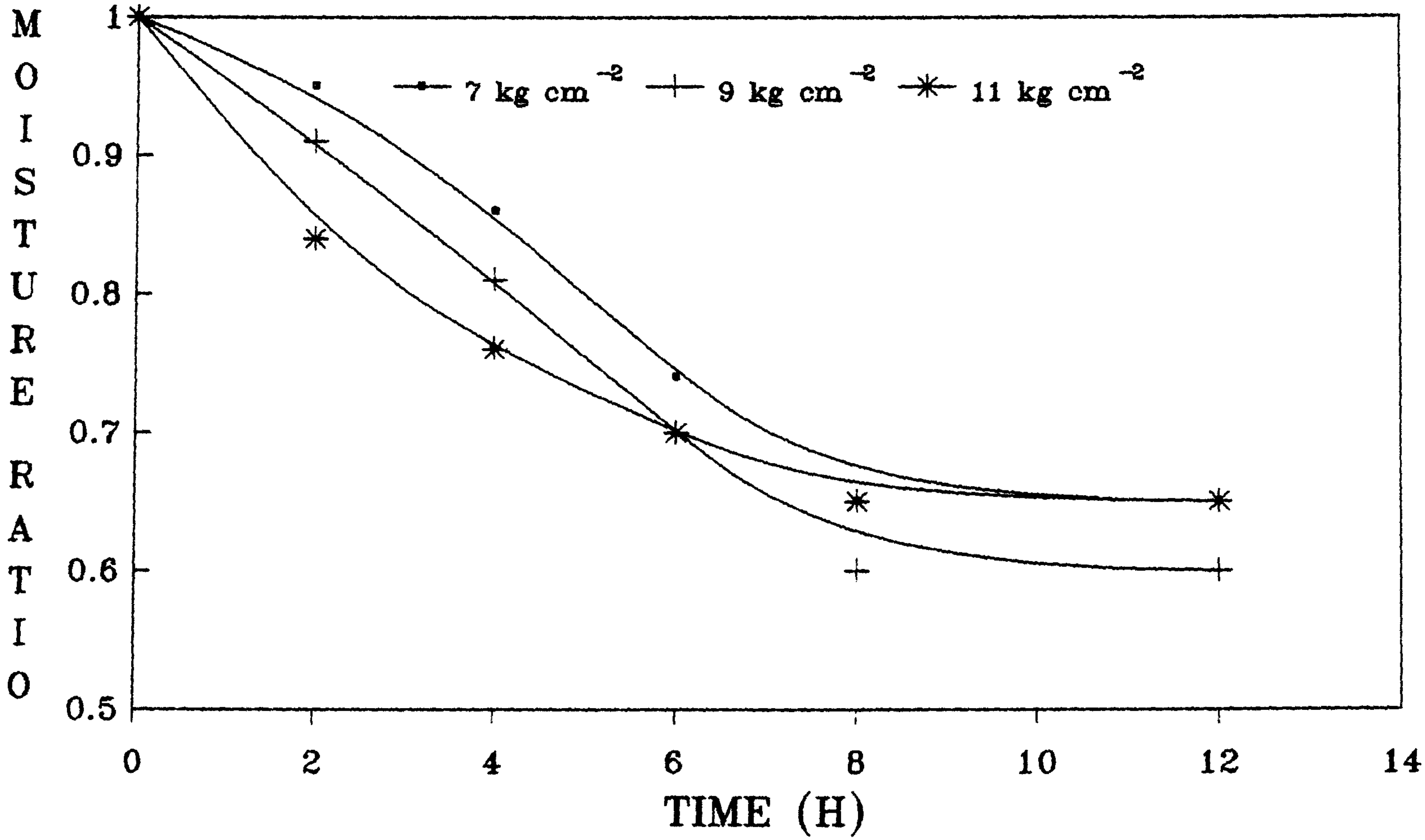

Fig. 21 ·Effect of time of pressing on moisture ratio (MR)

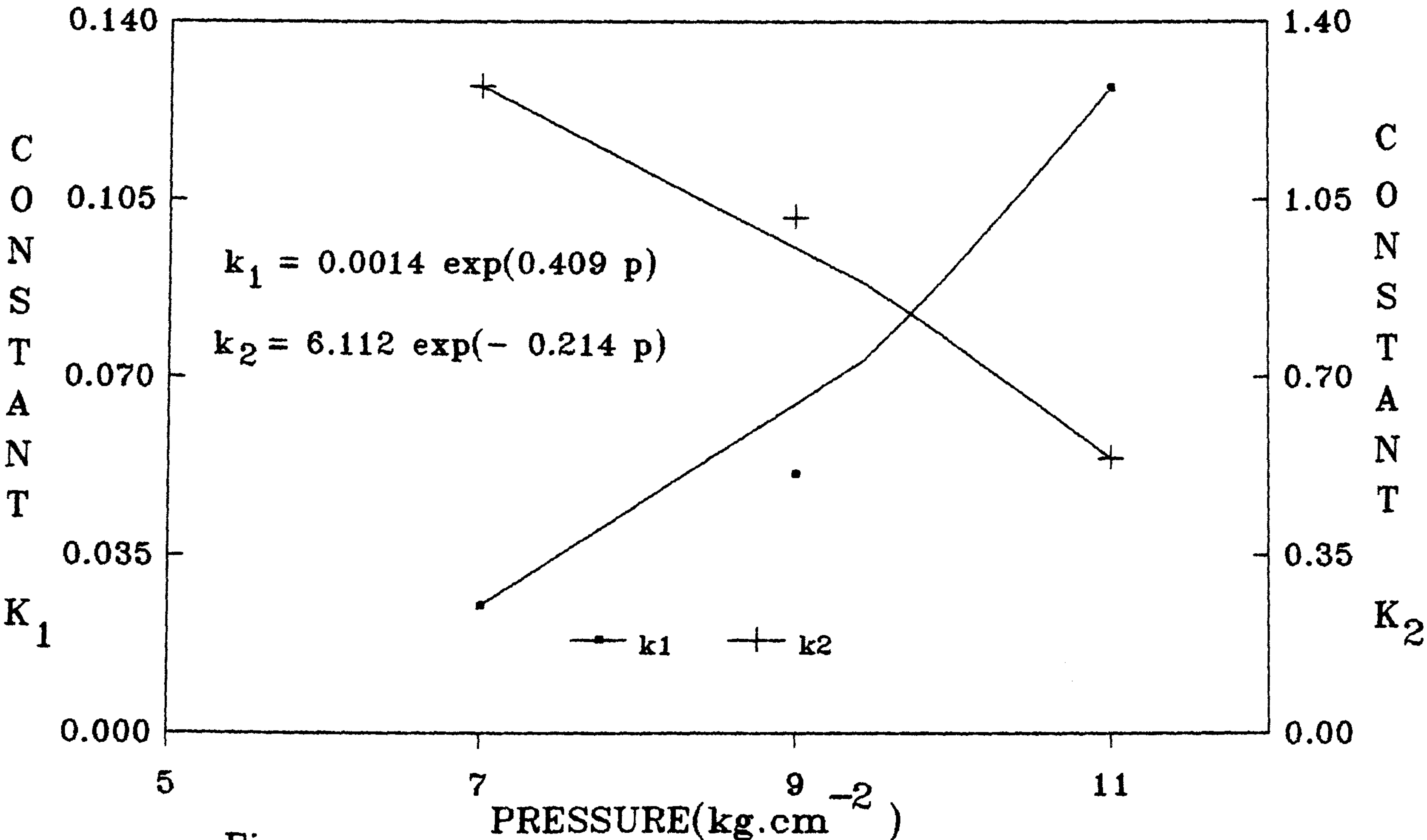

Fig. 22 · Effect of pressure on constants k_1 and k_2

Cohesiveness of churpi increased with time of pressing (Fig. 23).For pressing times greater than 4 h, the rate of increase in cohesiveness was maximum at 9 $kg.cm^{-2}$. Cohesiveness was correlated to time of pressing by a relationship:

$C = k_3 \ln t + k_4$, where k_3 and k_4 are pressure dependent constants.Constants of equation at different pressures were evaluated by least square regression of experimental data. The variation of k_3 and k_4 is plotted against pressure in Fig. 24. The relationship can be expressed as:

$$k_3 = -2.285 + 0.6p - 0.037p^2$$
$$k_4 = 2.18 - 0.59p + 0.035p^2$$

A unified model for cohesiveness in a sample of churpi may thus be represented by the equation:

$$C = 2.18 - 0.59p + 0.035p^2 + \{-2.285 + 0.6p - 0.037p^2\}. \ln t$$

Springiness of churpi increased with time of pressing (Fig. 25). For pressing times greater than 6 h, the rate of increase in springiness was maximum at 9 $kg.cm^{-2}$. Springiness was correlated to time of pressing by a relationship of the form:

$Spr = k_6 + k_5 \ln t$, where k_5 and k_6 are pressure dependent constants. Constants of equations at different pressures were evaluated by least square regression of the experimental data. The variations of k_5 and k_6 are plotted against pressure in Fig. 26. The relationship can be expressed as:

$$k_5 = 0.523 \exp(-0.093p)$$
$$k_6 = 1.8 \times 10^{-10} \exp(1.905p)$$

A unified model for springiness in a sample of churpi may thus be represented by the equation:

$$Spr = 1.8 \times 10^{-10} \exp(1.905p) + \{0.523 \exp(-0.093p)\}.\ln t$$

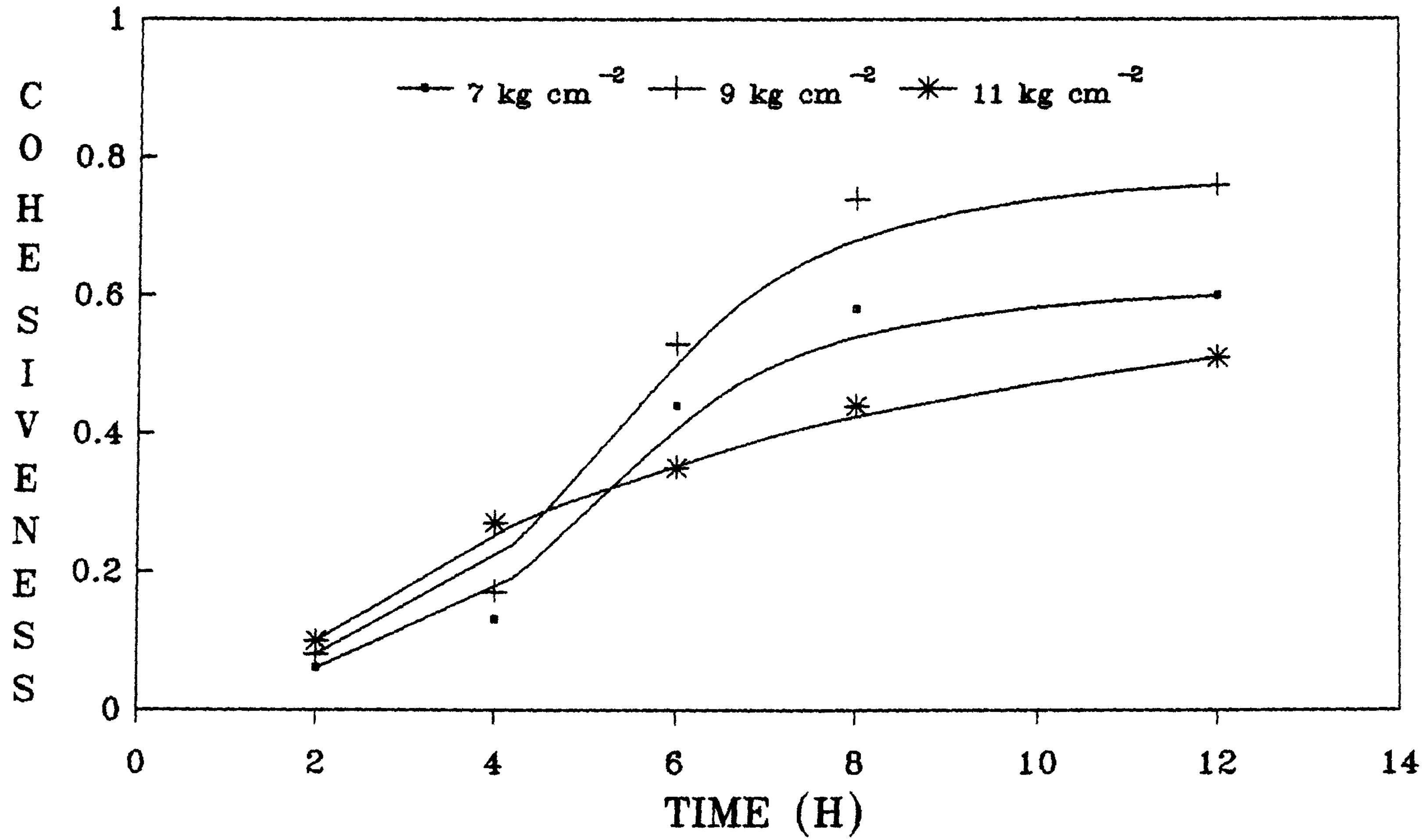

Fig. 23 ·Effect of time of pressing on cohesiveness (C)

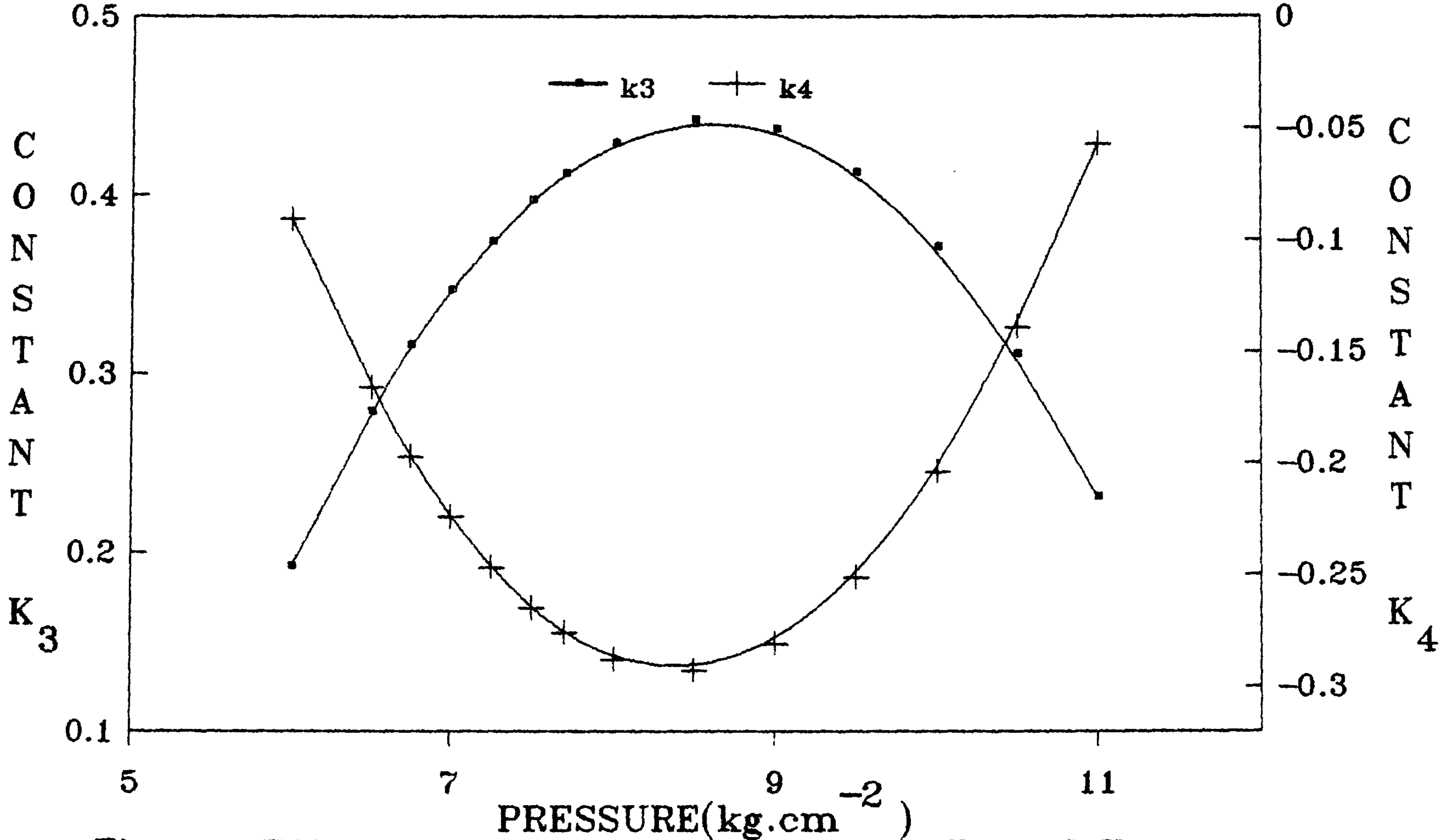

Fig. 24 . Effect of pressure on constants K_3 and K_4

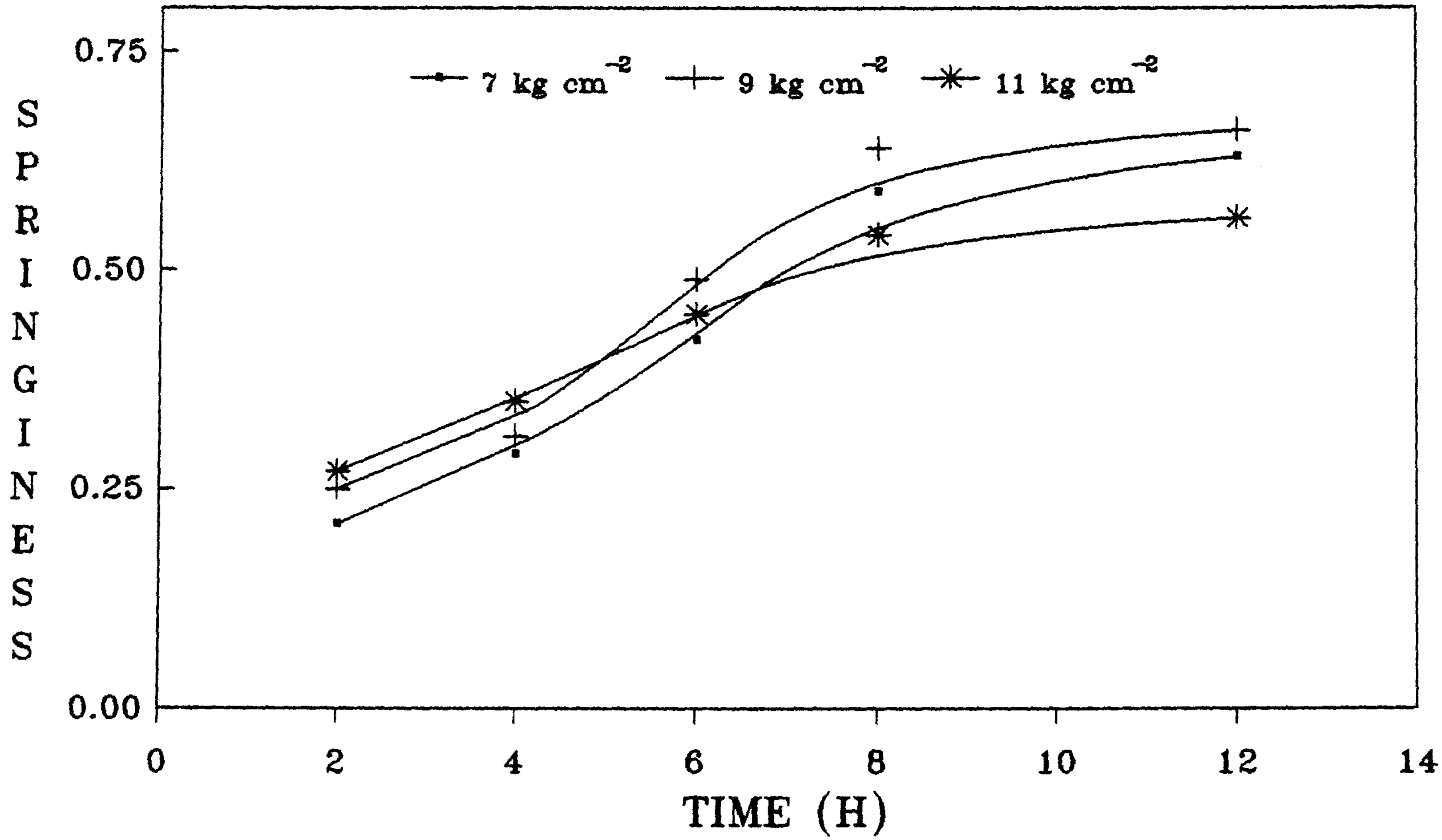

Fig. 25 · Effect of time of pressing on springiness (mm)

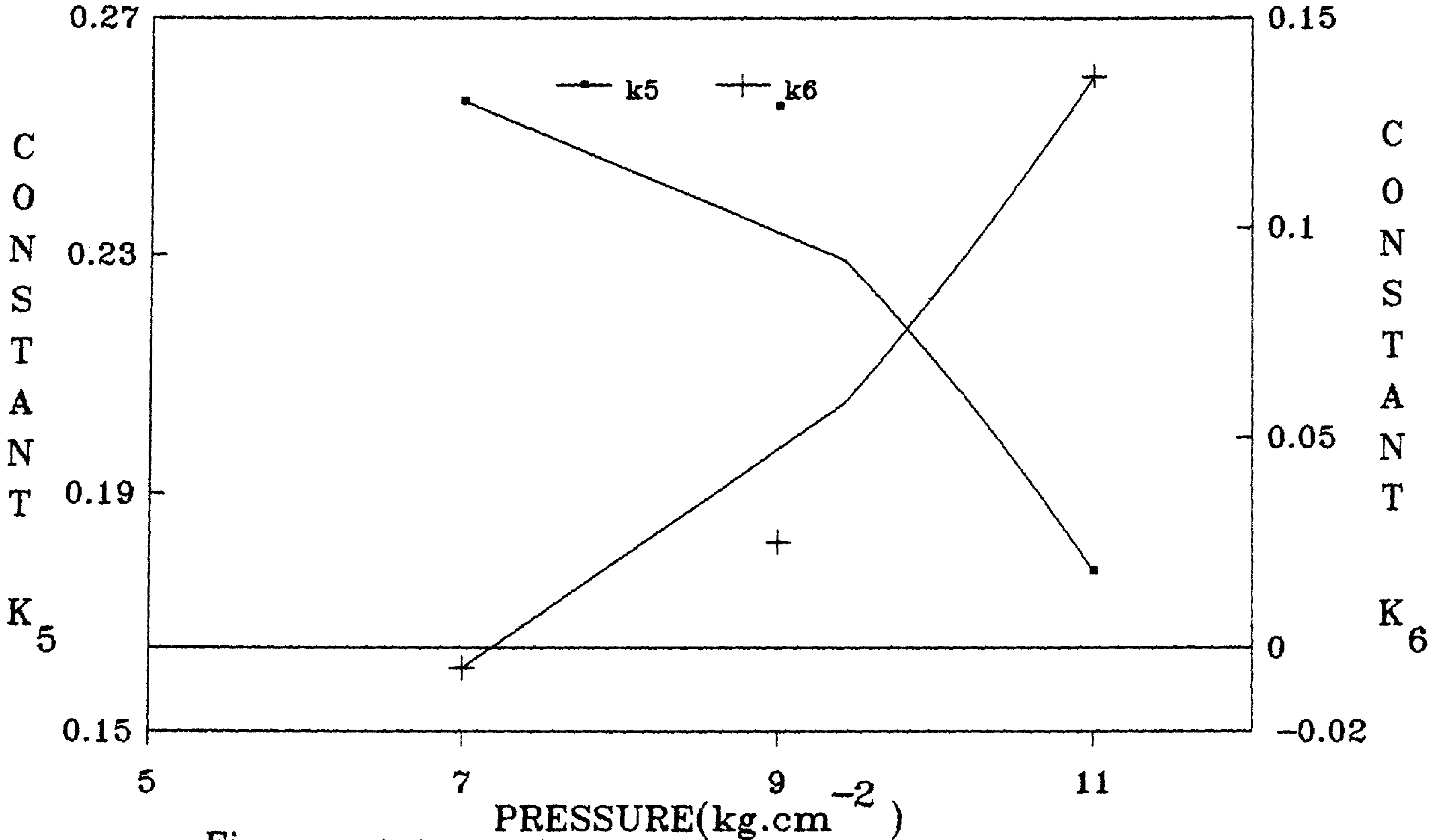

Fig. 26 · Effect of pressure on constants k5 and k6

4.3.8. Drying behaviour as effected by size of churpi

The plots of moisture ratio versus time of drying for different sizes of churpi are shown in Fig. 27. Maximum and minimum drying temperature and relative humidity at different days of drying are presented in Table 28. The rate of moisture ratio reduction was less in the samples of larger sizes. The rate of drying decreased with the time of drying until a constant moisture content was reached. The moisture content variation during drying was monitored by the formula of material balance, Q_1 (100 - M_1) = Q_2 (100 - M_2), where Q_1 and Q_2 are initial and final weights in g and M_1 and M_2 are moisture contents on wet basis at Q_1 and Q_2. The rate of drying was expressed by the model (Page 1949):

$$MR = \frac{M_t - M_e}{M_o - M_e} = \exp(-ptQ)$$

where M_t = moisture content at time t, M_e = equilibrium moisture content and M_o= initial moisture content. The constants p and Q are found to depend upon temperature and relative humidity of the drying air. The effects of size on the rate of drying of churpi pieces can be evaluated by considering the time of half-response ($t_{\frac{1}{2}}$). The $t_{\frac{1}{2}}$ is defined as the time required to remove the first half of the free moisture. This corresponds to the time required to reach a moisture ratio of 0.5. Drying equations and $t_{\frac{1}{2}}$ as evaluated by Page's model are presented in Table 29. The constants p and Q can be expressed in the form:

$$p = 1.625 - 0.015T - 0.021RH$$

$$Q = 2.984 - 0.030T - 0.012RH$$

where, T denotes temperature and RH denotes relative humidity.

The instron texture profile of churpi of three different

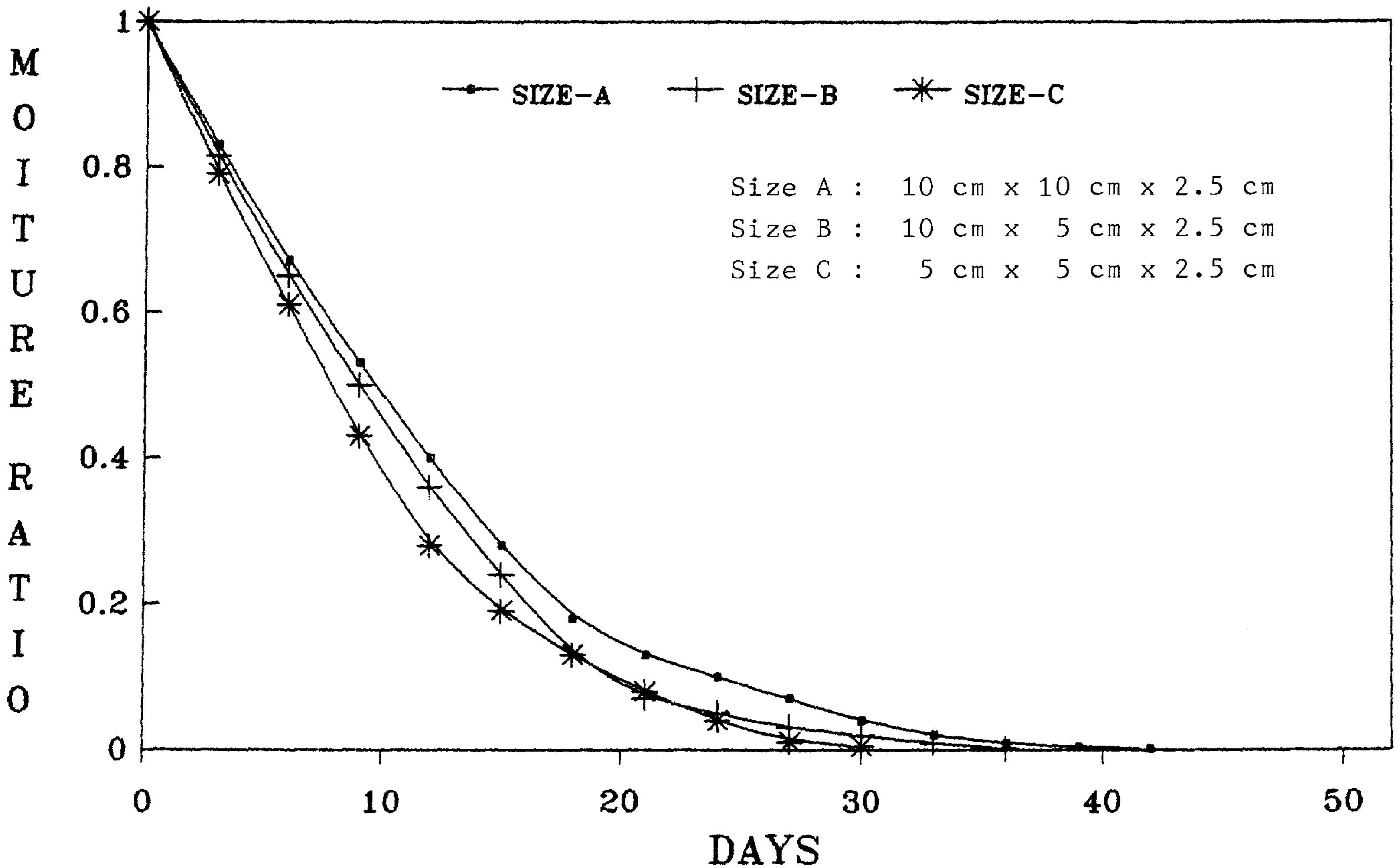

Fig. 27 . Drying behaviour as effected by size of churpi

Table 28. Maximum and minimum temperature and relative humidity at different days of drying

Day	Temperature (°C)		Relative humidity (%)	
	Maximum	Minimum	Maximum	Minimum
0	41.5	27.5	67.00	36.00
3	40.0	26.5	62.00	33.00
6	39.5	27.5	64.00	30.00
9	43.0	28.0	66.00	34.00
12	42.5	27.5	65.00	31.50
15	41.5	26.0	66.60	31.25
18	39.5	27.5	65.70	39.00
21	42.5	28.0	69.75	37.25
24	43.0	29.5	65.40	33.50
27	41.5	29.0	66.60	32.25
30	42.0	28.5	67.80	33.00
33	41.0	28.0	69.50	32.50
36	43.0	30.0	68.80	32.15
39	42.5	27.5	66.20	34.50
42	41.0	26.0	64.30	33.25
45	42.5	27.0	61.70	32.15
48	43.0	28.5	66.50	33.60

Table 29. Drying equations and the time of half-response as evaluated from Page's model

Size of churpi	Equations developed	Time of half-response ($t_{\frac{1}{2}}$) (day)
A (10cm x 10cm x 2.5cm)	$MR = e^{-0.047\, t^{1.342}}$	7.43
B (10cm x 5cm x 2.5cm)	$MR = e^{-0.037\, t^{1.379}}$	8.28
C (5cm x 5cm x 2.5cm)	$MR = e^{-0.036\, t^{1.346}}$	9.07

MR, moisture ratio

sizes are shown in Table 30. No difference ($P<0.05$) was observed among the instron parameters of churpi of three different sizes.

4.4. Consumer response to laboratory-made churpi

The consumers' preference trial (Table 31) with the samples of churpi from Bhutan market and those prepared in laboratory indicates an equal acceptance of the laboratory-made product and the best available market product.

All the respondents within the age group of 20-45 years expressed their frequency of eating churpi either as 'several times a week' or 'several times a month'. None of the respondents mentioned any specific time of eating this product.

Out of 200 respondents, 102 preferred market churpi over laboratory-made churpi. Eighty-seven % and 13% indicated their reasons for preference as better colour and overall sensory quality, respectively. Out of 98 respondents who preferred laboratory-made churpi, 46% indicated better flavour, 32% better texture, and 22% both flavour and texture as their reasons for preference.

4.5. Changes in sensory attributes and phsico-chemical parameters during manufacturing churpi

Changes in sensory attributes during manufacturing churpi are presented in Table 32. Flavour, body and texture, gumminess and chewiness and total scores increased significantly ($P<0.001$) at every seven days intervals from 0 day to 42nd day. No change ($P<0.001$) in colour and appearance was observed within first 7 days. However, from 7th to 35th day there was an increase in colour and appearance score. Maximum score was obtained on 42nd day.

Table 30. Instron texture profile of churpi of three different sizes

Instron parameters	Size A (10 cm x 10 cm x 2.5 cm)	Size B (10 cm x 5 cm x 2.5 cm)	Size C (5 cm x 5 cm x 2.5 cm)
Hardness (N)	1000.15[a] (999.00-1015.00)	999.75[a] (995.00-1015.00)	998.30[a] (994.40-1010.00)
Cohesiveness	0.76[a] (0.70-0.84)	0.76[a] (0.71-0.84)	0.76[a] (0.70-0.83)
Springiness (mm)	0.66[a] (0.60-0.81)	0.65[a] (0.61-0.78)	0.66[a] (0.60-0.80)
Gumminess (N)	766.97[a] (760.20-845.21)	762.21[a] (751.31-829.25)	760.11[a] (747.37-838.30)
Chewiness (N.mm)	505.28[a] (425.30-568.80)	515.29[a] (449.25-560.70)	502.92[a] (417.65-597.90)

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

Table 31. Consumers' response to market (Bhutan) and laboratory-made churpi

Overall response	No. of consumers	
	Market	Laboratory-made
Preferred extremely	15 (7.5)	17 (8.5)
Preferred very much	22 (11.0)	21 (10.5)
Preferred moderately	29 (14.5)	23 (11.5)
Preferred slightly	36 (18.0)	37 (18.5)

Per cent respondents are indicated in parentheses.

Table 32. Changes in sensory attributes during preparation of churpi

Attributes	Drying period (days)						
	0	7	14	21	28	35	42
Flavour	10.00^{a} (9.71-10.28)	16.14^{b} (15.85-16.43)	20.10^{c} (19.85-20.28)	24.10^{d} (23.85-24.28)	26.14^{e} (25.85-26.28)	30.10^{f} (29.85-30.43)	33.59^{g} (32.14-34.14)
Body and texture	8.00^{a} (7.71-8.28)	10.10^{b} (9.85-10.28)	13.54^{c} (13.43-13.71)	18.10^{d} (17.85-18.38)	21.10^{e} (20.85-21.29)	26.10^{f} (25.85-26.28)	28.25^{g} (28.14-29.14)
Colour and appearance	3.00^{a} (2.71-3.28)	3.07^{a} (2.71-3.43)	4.54^{b} (4.43-4.71)	5.10^{b} (4.85-5.28)	6.50^{c} (6.42-6.57)	8.14^{d} (7.85-8.28)	8.61^{d} (8.15-9.28)
Gumminess and chewiness	5.07^{a} (4.71-5.43)	7.03^{b} (6.85-7.28)	11.03^{c} (10.85-11.28)	16.54^{d} (16.43-16.71)	19.10^{e} (18.85-19.28)	21.14^{f} (20.85-21.28)	23.28^{g} (22.57-24.28)
Total score	26.05^{a} (24.84-27.27)	36.34^{b} (35.26-37.42)	49.20^{c} (48.56-49.98)	63.84^{d} (62.98-64.65)	72.84^{e} (71.97-73.42)	85.48^{f} (84.40-86.27)	93.15^{g} (91.00-96.84)

Data represent the means of four replicates. Ranges are given in parentheses. Values bearing different superscripts in each row differ significantly ($P<0.001$).

The physico-chemical changes occurring during manufacture of churpi are presented in Table 33. The moisture content decreased ($P<0.001$) from initial 46.01% to 13.04% on 42nd day. Titratable acidity increased from 0.19% to 0.28% on 28th day, and no further increase of it was observed. There was an increase ($P<0.001$) in lactic acid within first 7 days. Free fatty acid increased ($P<0.001$) from 0.22% to 0.86% on 42nd day. The TBA value increased ($P<0.001$) at every 7 days intervals till 28th day. Tyrosine content also increased ($P<0.001$) at every 7days intervals till 35th day. Free and total HMF showed a steady increase ($P<0.001$) from 0 to 42 days. On the other hand, per cent reflectance showed a decrease ($P<0.001$) at every 7 days intervals till the end of drying. Figures 28 - 32 showed the regression lines and correlation coefficients (R) of flavour scores with titratable acidity (TA), lactic acid (LA), free fatty acid (FFA), 2-thiobarbituric acid (TBA) value and tyrosine (Ty) content of churpi. The correlation coefficeints calculated for TA, LA, FFA, TBA and Ty content with flavour scores over the entire period were highly significant ($P<0.001$). The correlation coefficients calculated for LA, total HMF, Ty and TA with body and texture scores were highly significant ($P<0.001$) over the entire period (Figs 33 - 36). The correlation coefficeints of TA and total HMF with colour and appearance scores were highly significant ($P<0.001$) (Figs 37, 38). The correlation coefficients calculated for total HMF, Ty, TA and LA with chewiness and gumminess were highly significant ($P<0.001$) over the entire period (Figs 39 - 42).

Regression equations of sensory attributes as influenced by intrinsic parameters during drying of churpi are presented in

Table 33. Changes in physico-chemical parameters during preparation of churpi

Parameters	Drying period (days)						
	0	7	14	21	28	35	42
Moisture (%)	46.01[a] (45.98-46.04)	32.42[b] (32.39-32.46)	21.55[c] (21.53-21.58)	15.47[d] (15.45-15.49)	13.96[e] (13.94-13.98)	13.17[f] (13.15-13.19)	13.04[f] (12.98-13.09)
Titratable acidity (as % lactic acid)	0.19[a] (0.18-0.20)	0.22[ab] (0.20-0.24)	0.24[bc] (0.23-0.25)	0.26[c] (0.25-0.27)	0.28[cd] (0.27-0.29)	0.28[d] (0.27-0.29)	0.28[d] (0.27-0.29)
Lactic acid (%)	0.01[a] (0.01-0.01)	0.02[b] (0.02-0.02)	0.02[b] (0.02-0.02)	0.02[b] (0.02-0.02)	0.03[c] (0.02-0.03)	0.03[c] (0.03-0.03)	0.03[c] (0.03-0.03)
Free fatty acid (as % oleic acid)	0.22[a] (0.20-0.24)	0.44[b] (0.40-0.46)	0.52[c] (0.50-0.54)	0.62[d] (0.58-0.66)	0.70[e] (0.67-0.73)	0.79[f] (0.77-0.81)	0.86[g] (0.84-0.88)
2-Thiobarbituric acid value (A_{425})	0.01[a] (0.01-0.01)	0.02[b] (0.02-0.03)	0.04[c] (0.04-0.04)	0.05[d] (0.05-0.05)	0.06[e] (0.05-0.06)	0.06[e] (0.05-0.06)	0.06[e] (0.05-0.06)
Tyrosine (mg/g)	0.07[a] (0.07-0.07)	0.11[b] (0.10-0.11)	0.12[c] (0.12-0.12)	0.13[d] (0.13-0.13)	0.14[e] (0.14-0.14)	0.15[f] (0.14-0.15)	0.15[f] (0.14-0.15)
Free HMF (µg/g)	15.48[a] (15.46-15.50)	18.22[b] (18.19-18.25)	21.39[c] (21.37-21.43)	24.62[d] (24.59-24.65)	26.77[e] (26.74-26.80)	27.55[f] (27.52-27.57)	28.01[g] (27.98-28.04)
Total HMF (µg/g)	35.51[a] (35.47-35.54)	40.42[b] (40.40-40.44)	46.28[c] (46.22-46.34)	52.36[d] (52.32-52.40)	55.66[e] (55.62-55.70)	59.25[f] (59.18-59.32)	61.39[g] (61.00-61.98)
Reflectance (%)	68.00[a] (67.50-68.50)	56.25[b] (56.00-56.50)	46.40[c] (46.10-46.80)	40.13[d] (39.80-40.50)	36.25[e] (35.70-36.80)	33.15[f] (32.80-33.40)	30.68[g] (30.40-31.00)

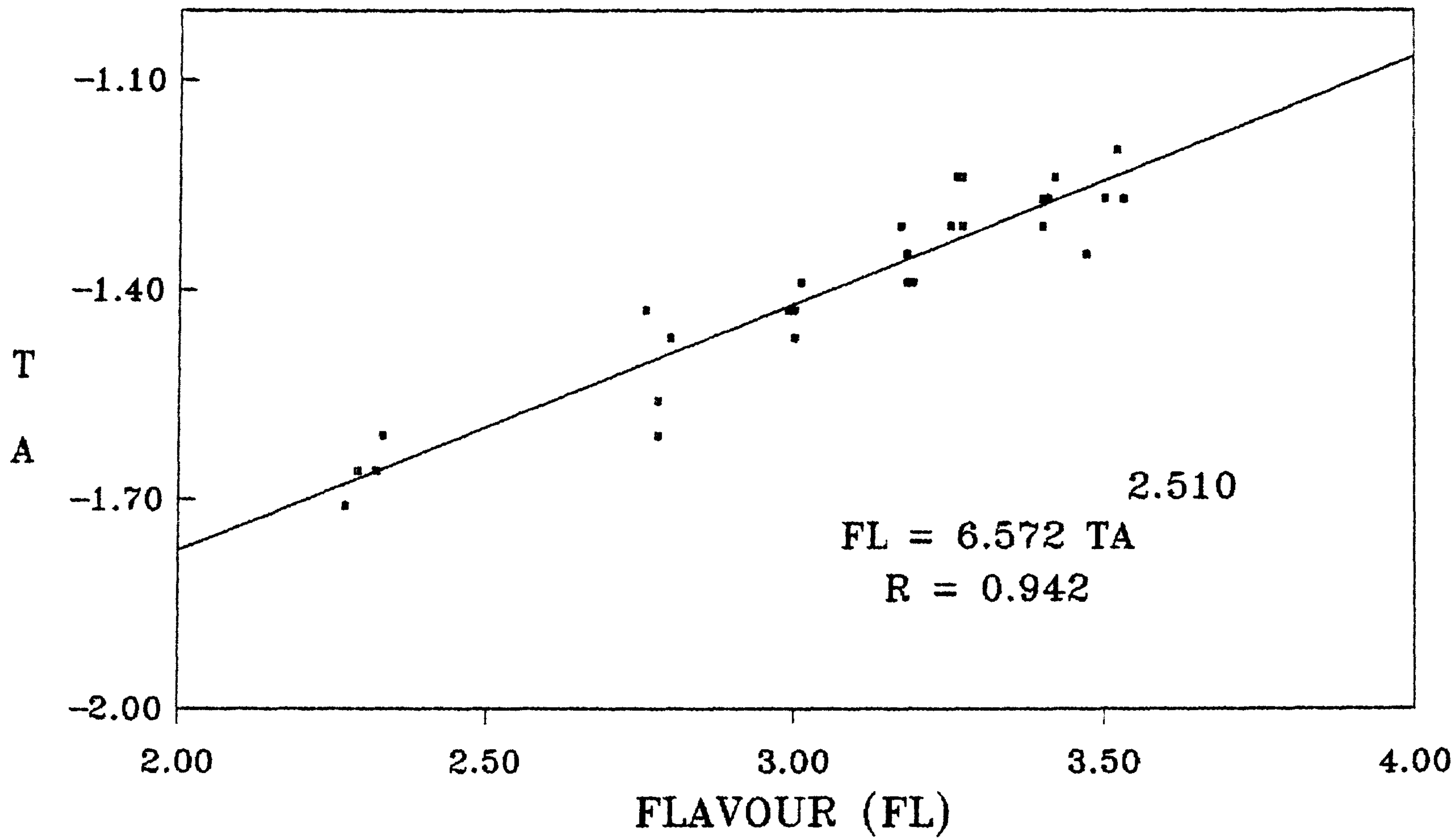

Fig. 28 . Relationship between flavour(FL) scores and titratable acidity (TA%) of churpi at different days of drying

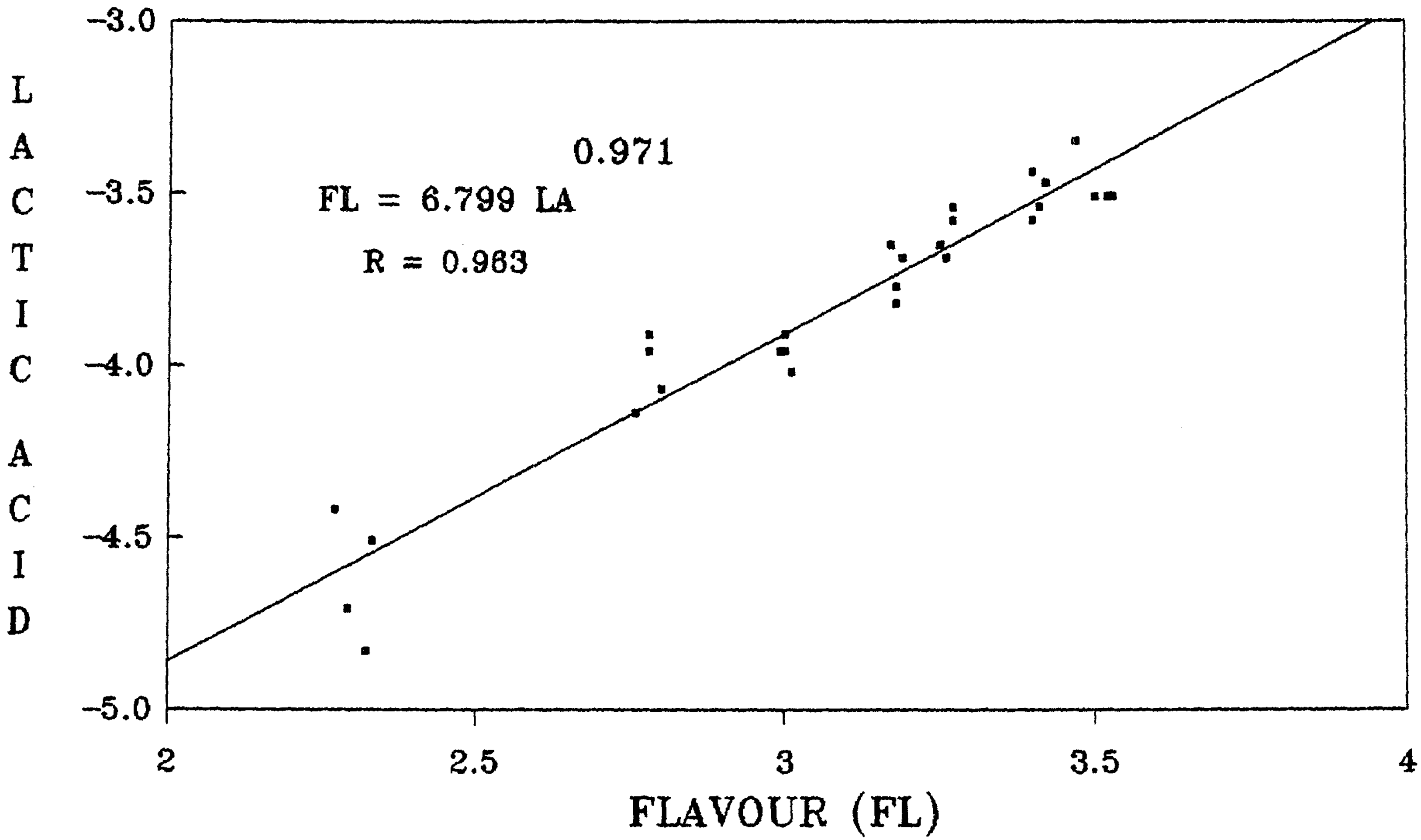

Fig. 29 . Relationship between flavour(FL) scores and lactic acid (LA%) of churpi at different days of drying

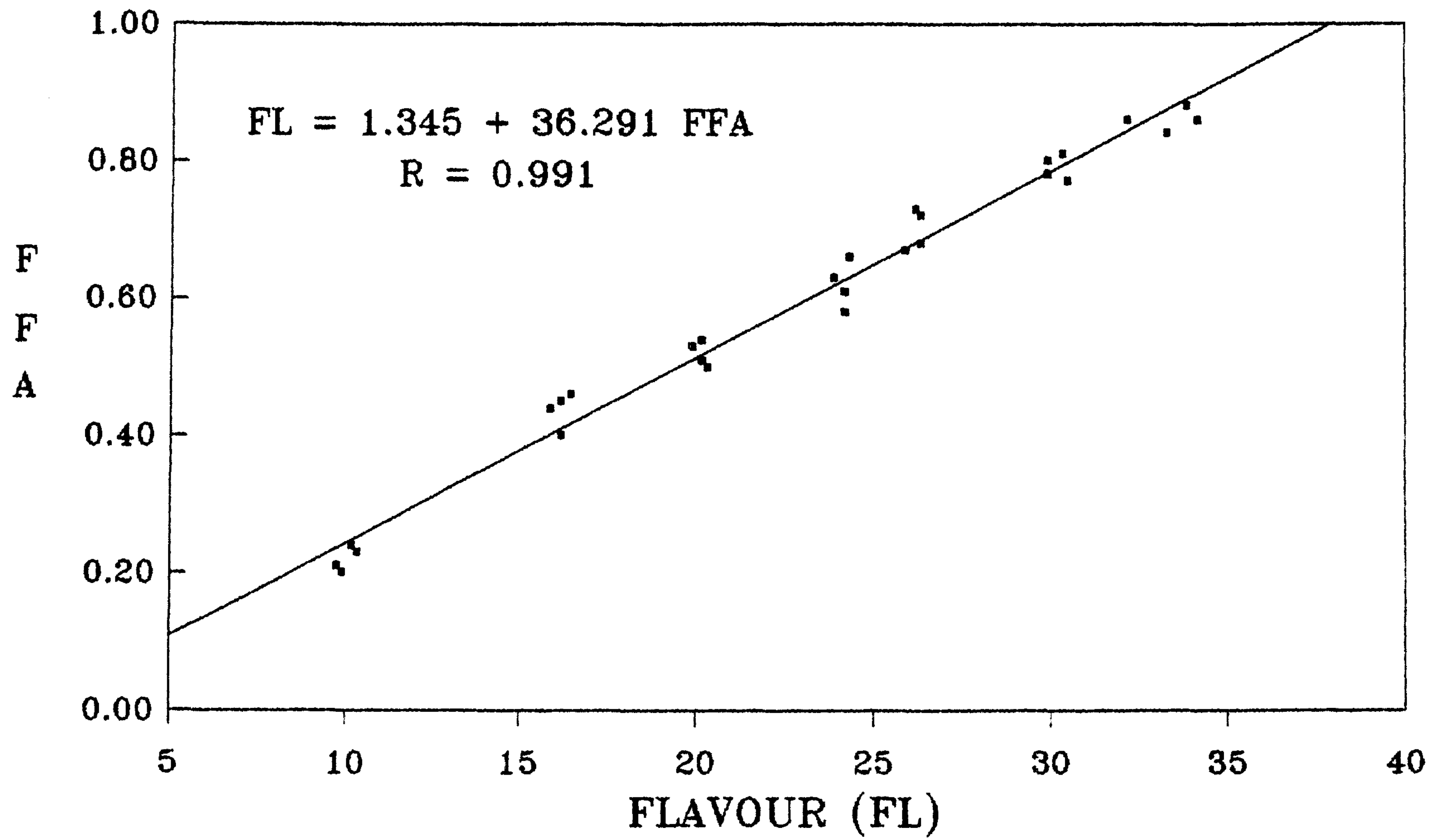

Fig. 30 . Relationship between flavour (FL) scores and free fatty acid (FFA%) of churpi at different days of drying

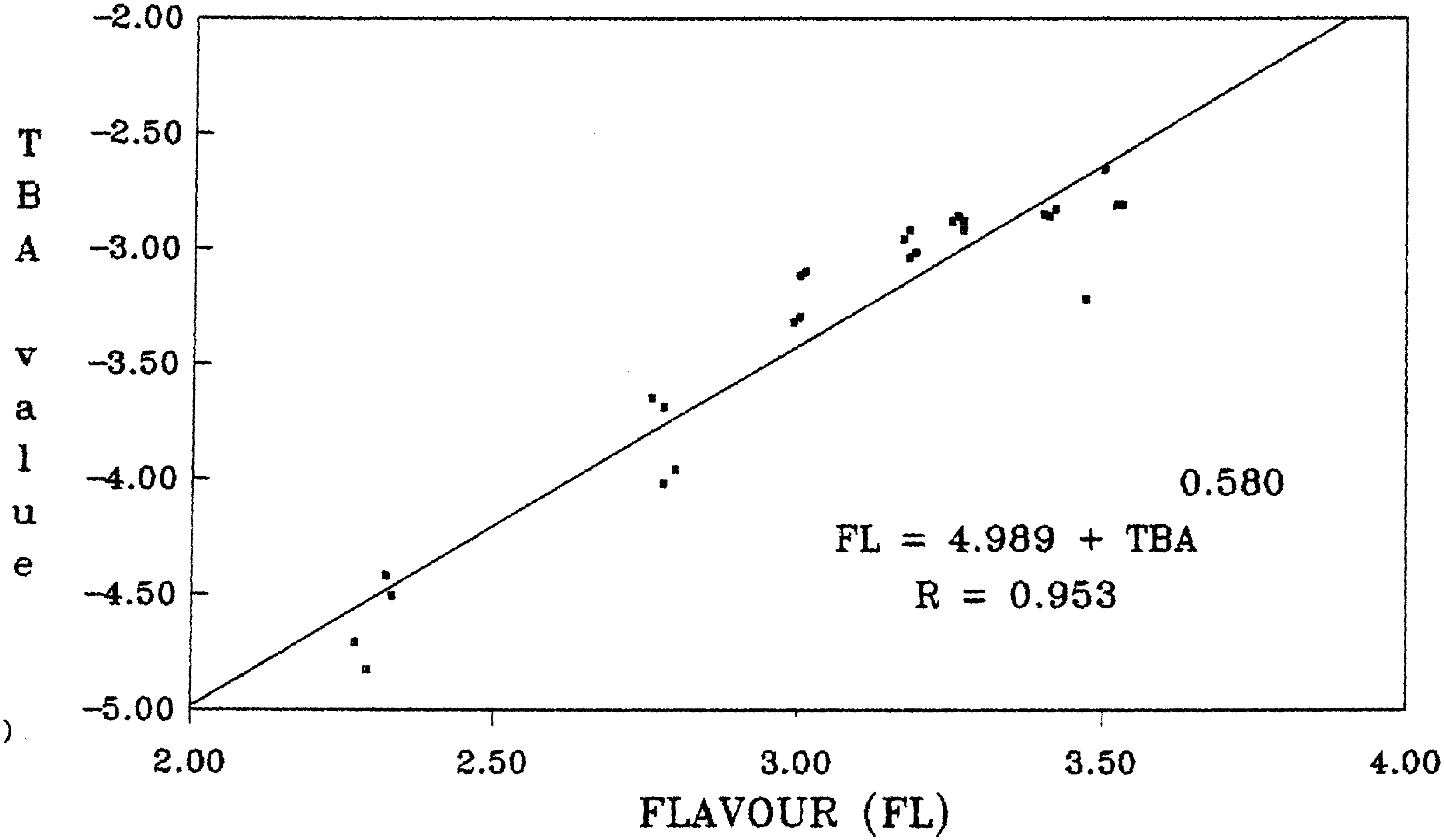

Fig.31. Relationship between flavour (FL) scores and thiobarbituric acid (TBA) value of churpi at different days of drying

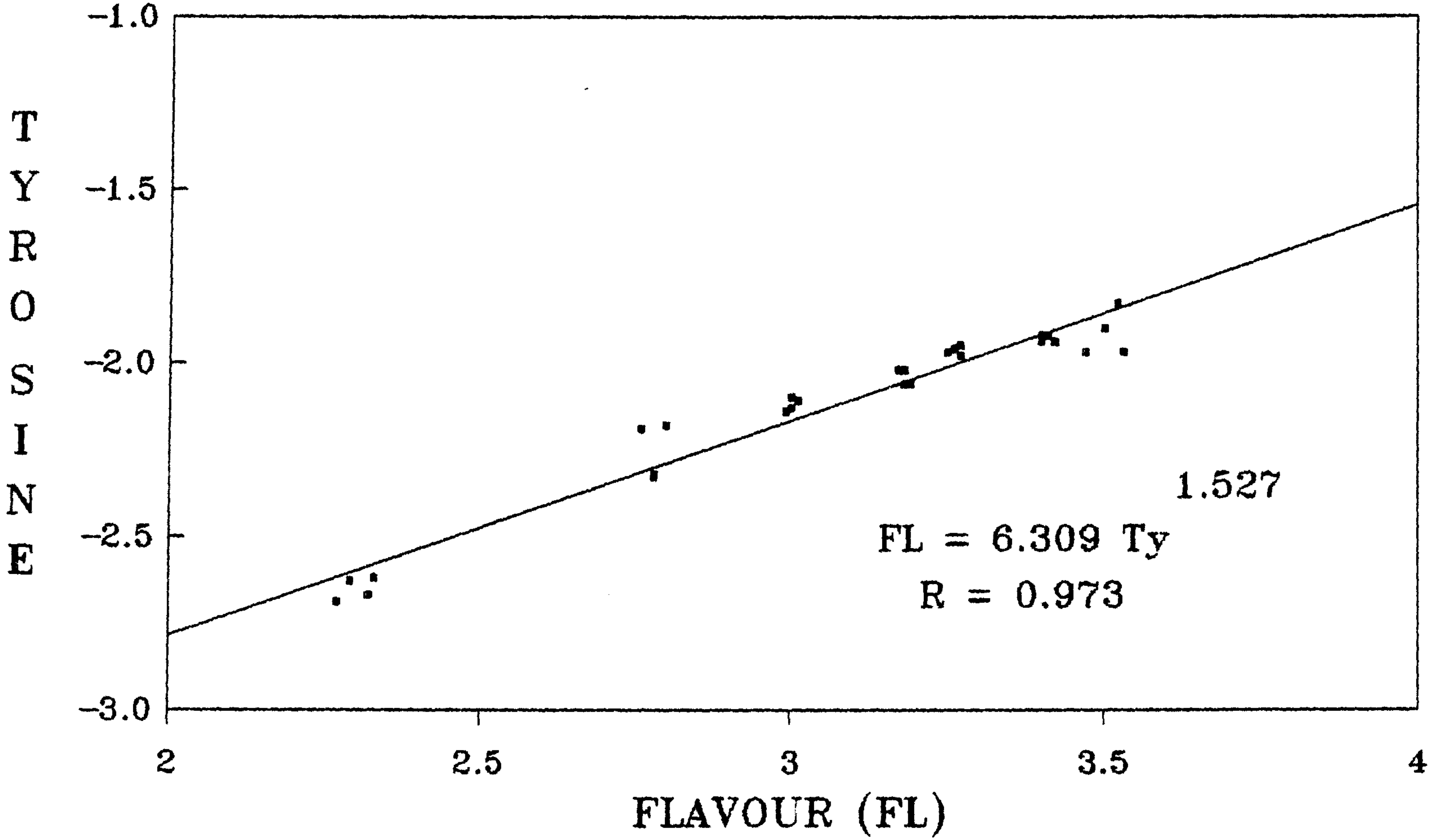

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Fig. 32 . Relationship between flavour (FL) scores and tyrosine (Ty) of churpi at diffrent days of drying

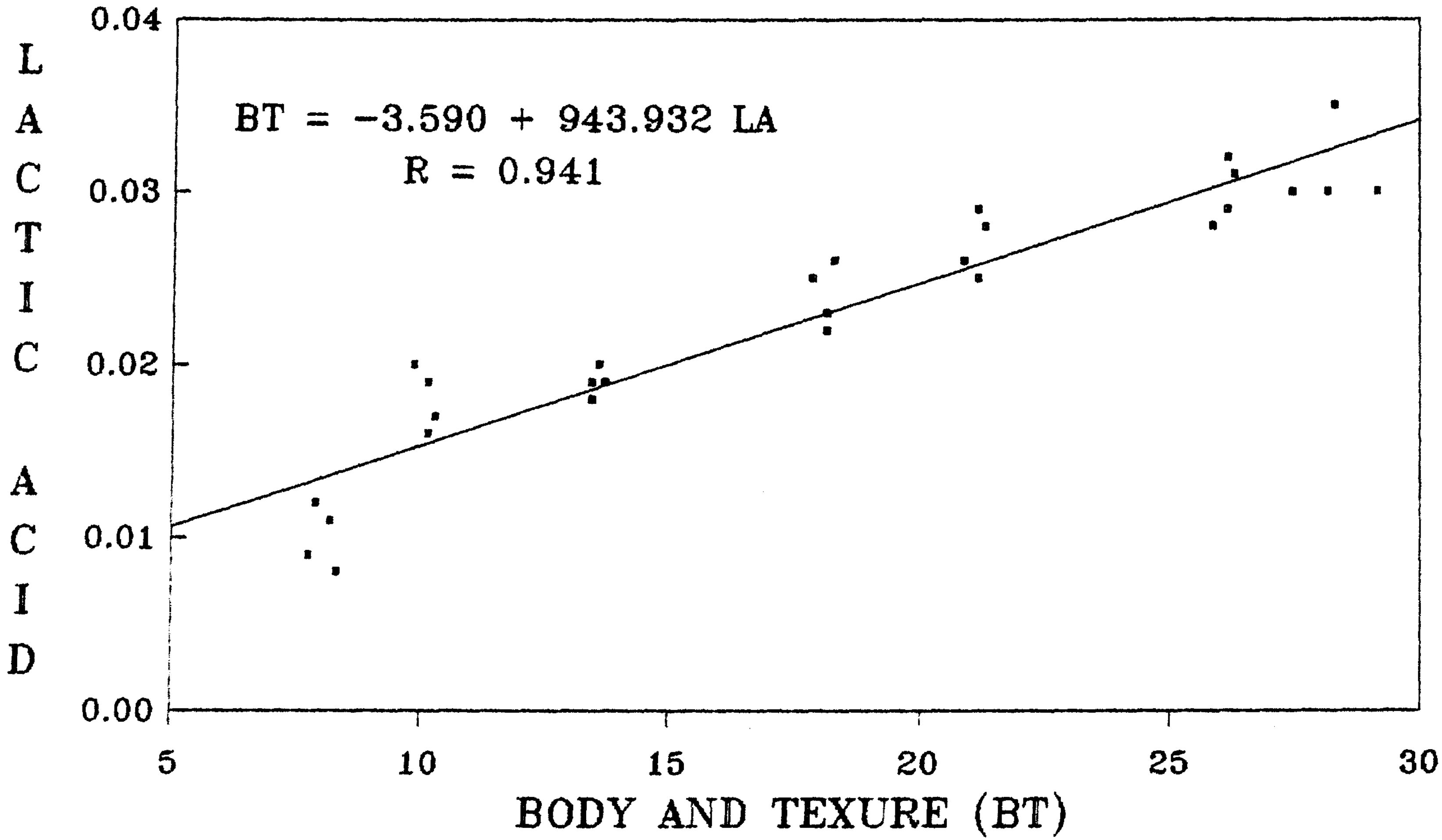

Fig. 33 .Relationship between body and texure(BT) scores and lactic acid(LA%) of churpi at different days of drying

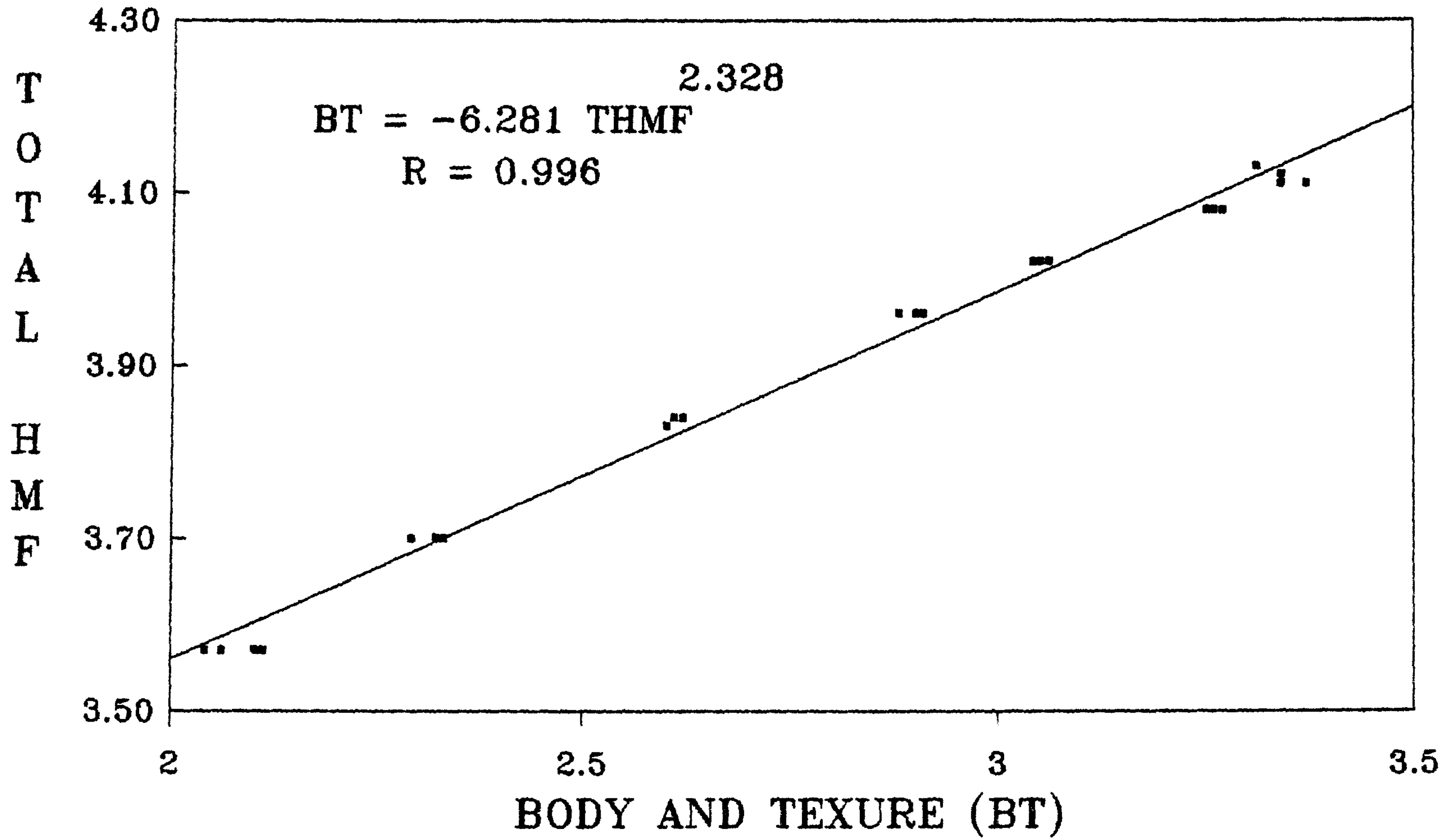

Fig. 34 .Relationship between body and texure(BT) scores and total HMF (micro moles/g) of churpi at diffrent days of drying

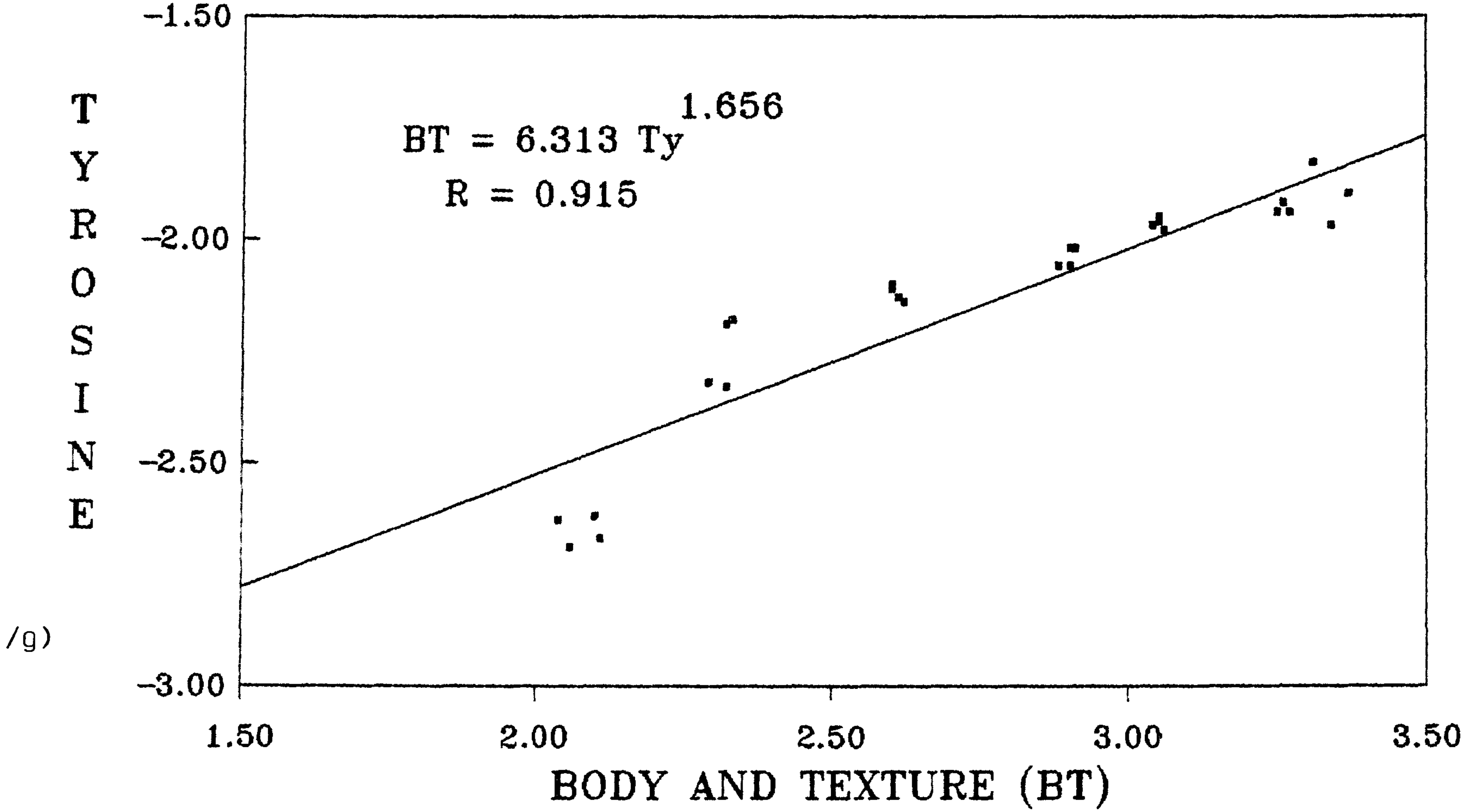

Fig. 35 . Relationship between body and texture (BT) scores and tyrosine(Ty) content of churpi at different days of drying

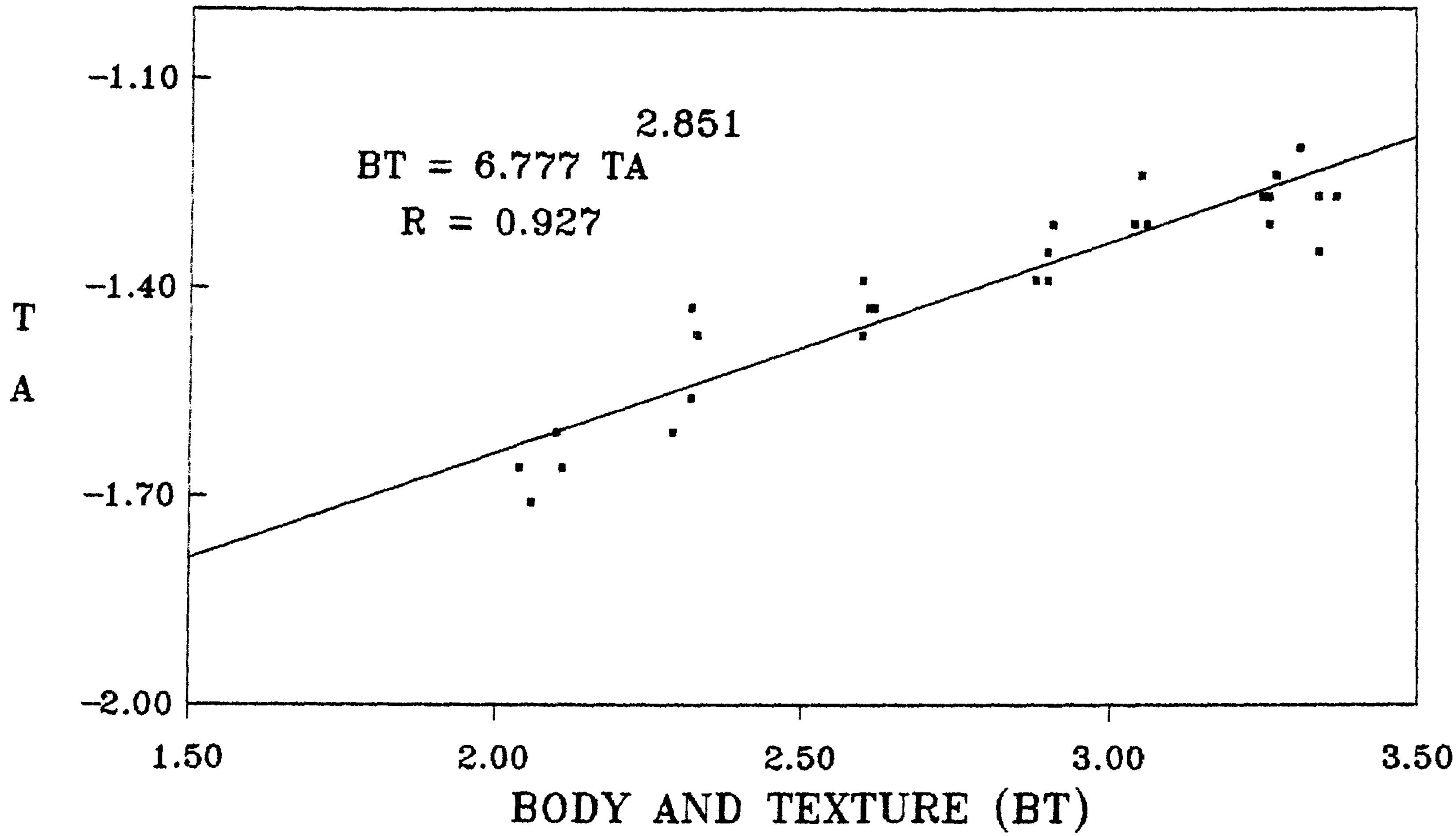

Fig. 36. Relationship between body and texture (BT)scores and tritatable acidity(TA%) of churpi at different days of drying

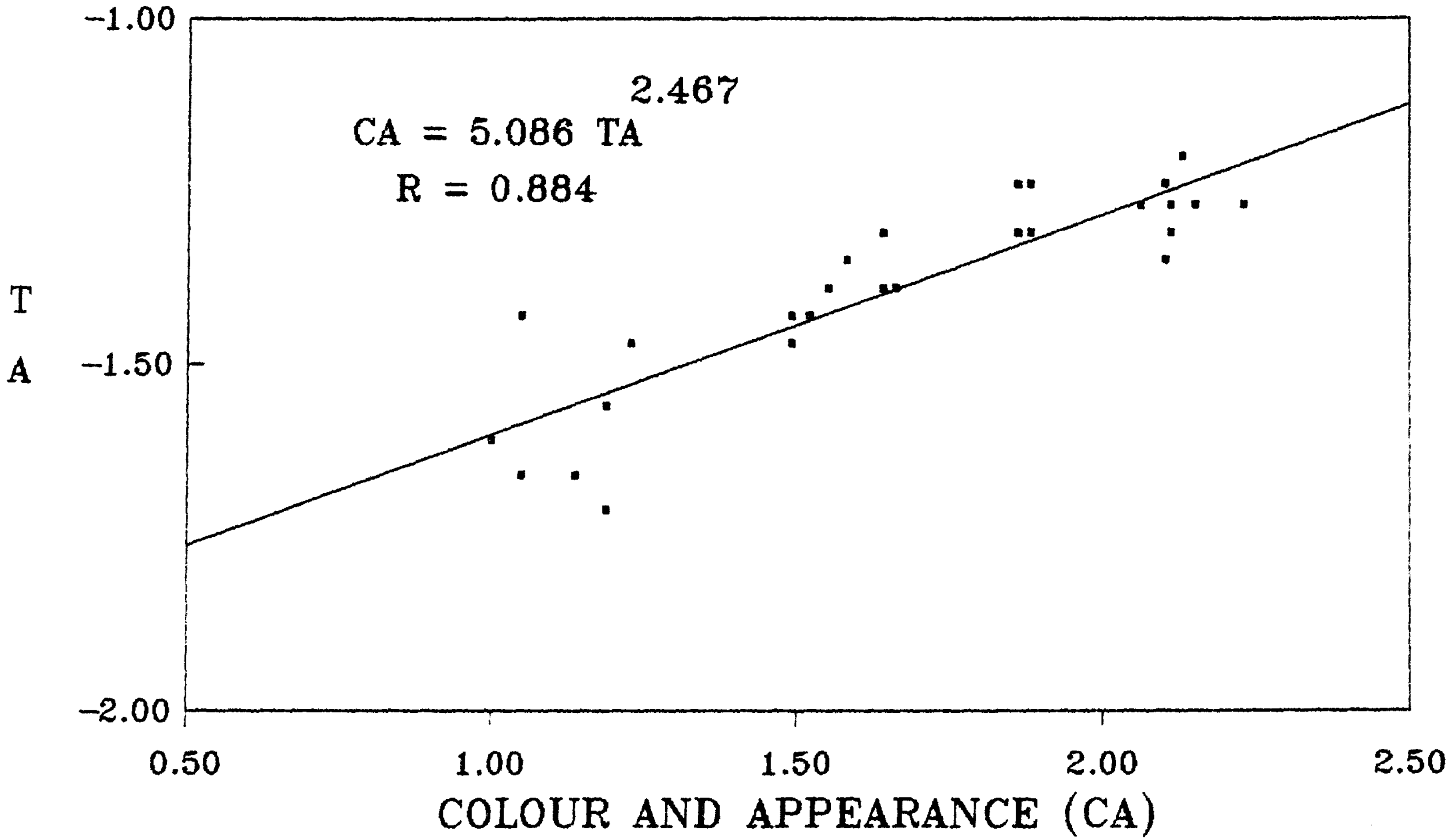

Fig. 37 . Relationship between colour and appearance (CA) scores and tritatable acidity(TA%) of churpi at different days of drying

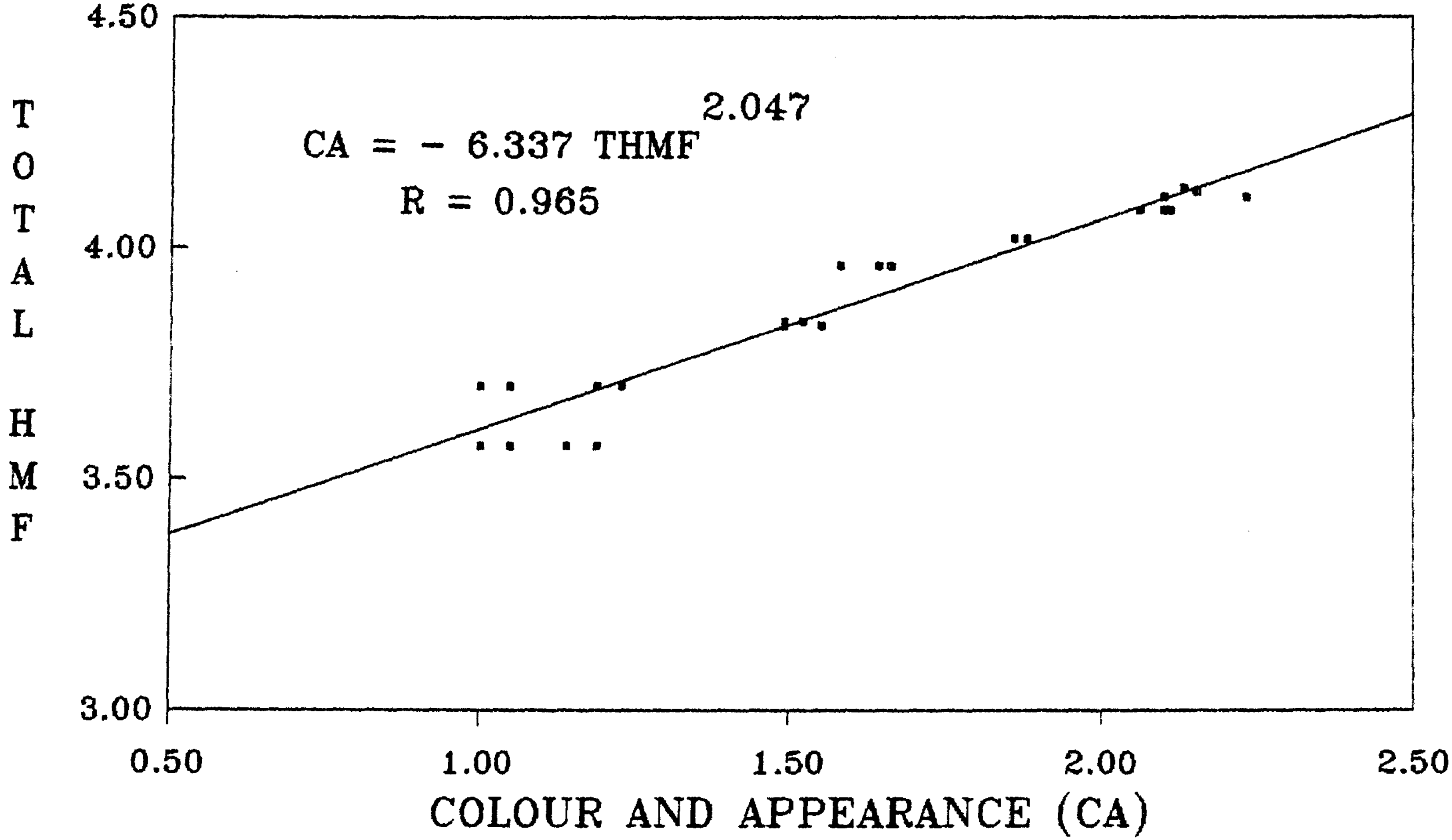

Fig. 38 .Relationship between colour and appearance (CA)scores and total HMF(micro moles/g) of churpi at different days of drying

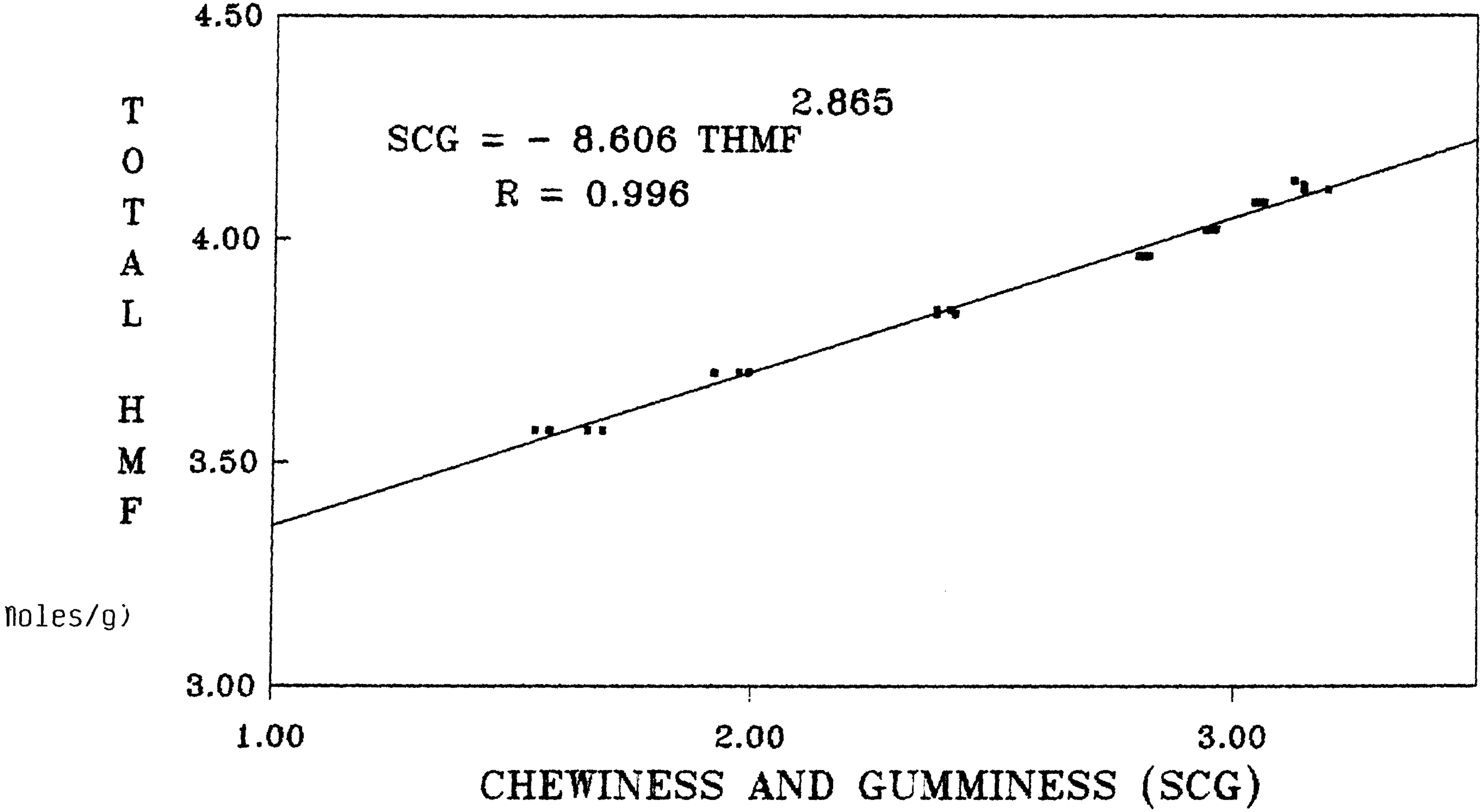

Fig. 39 . Relationship between chewiness and gumminess (SCG) scores and total HMF of churpi at different days of drying

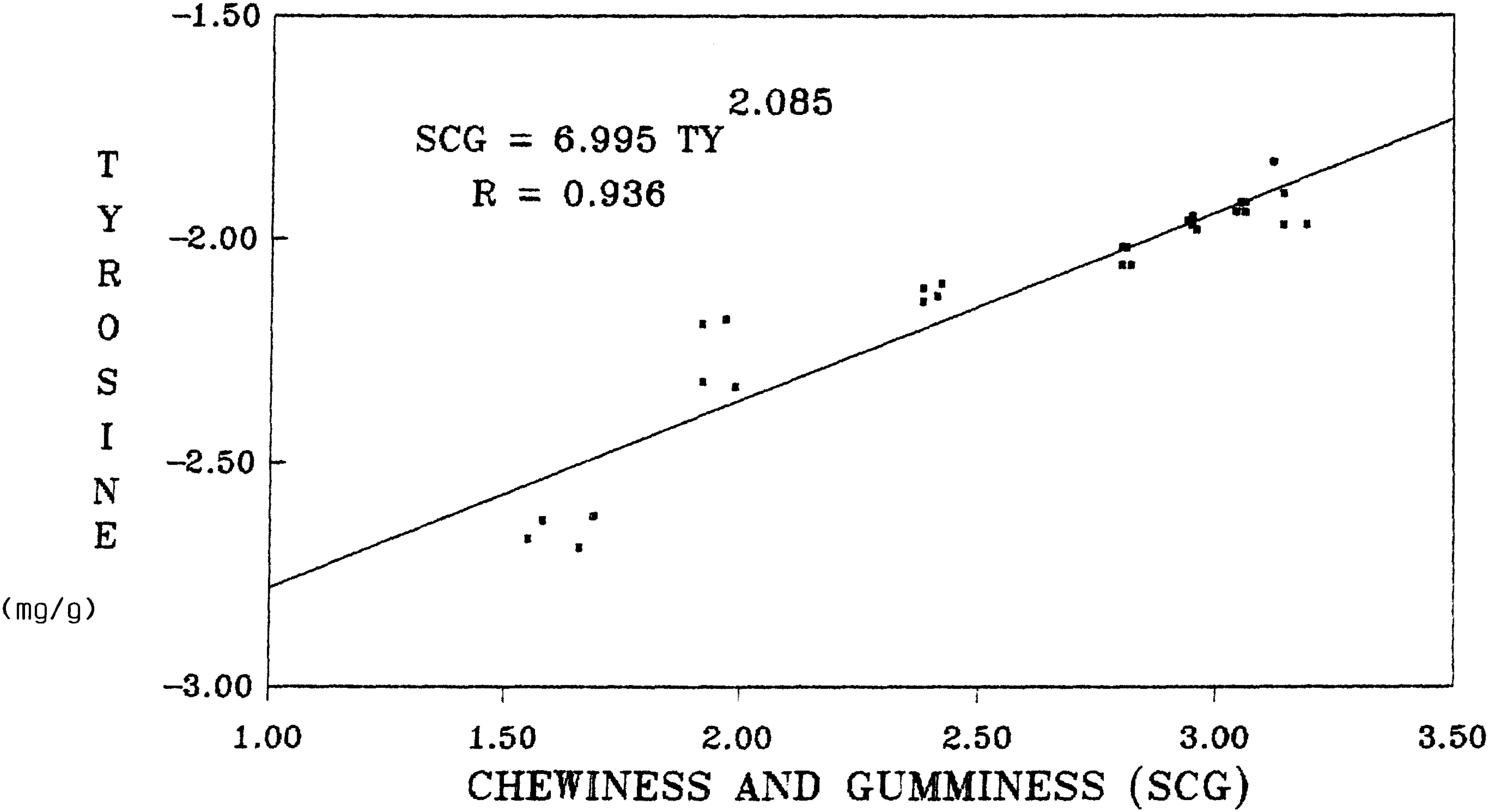

Fig. 40 . Relationship between chewiness and gumminess scores and tyrosine content of churpi at different days of drying

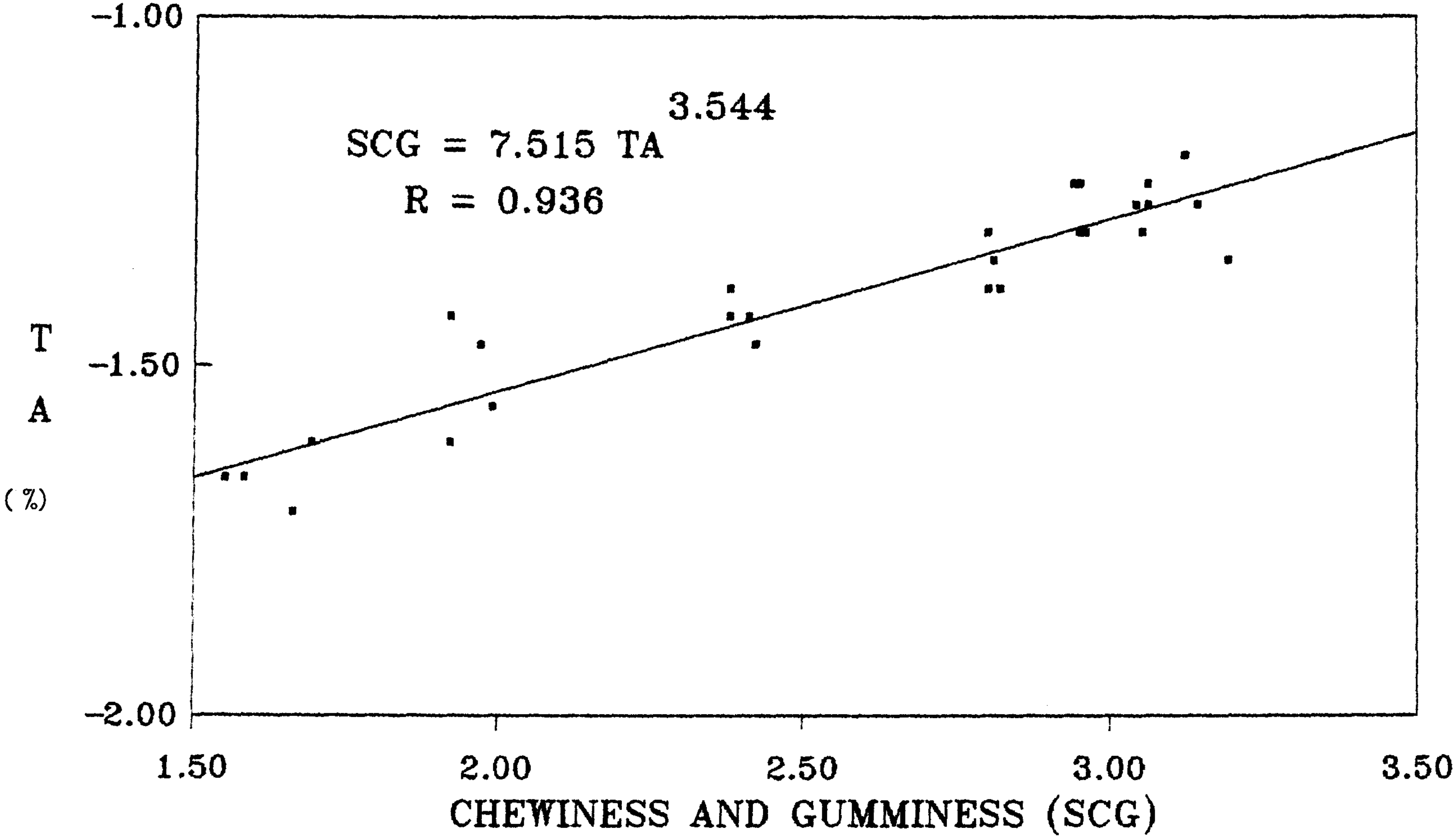

Fig. 41 . Relationship between chewiness and gumminess scores and tritatable acidity of churpi at diffrent days of drying

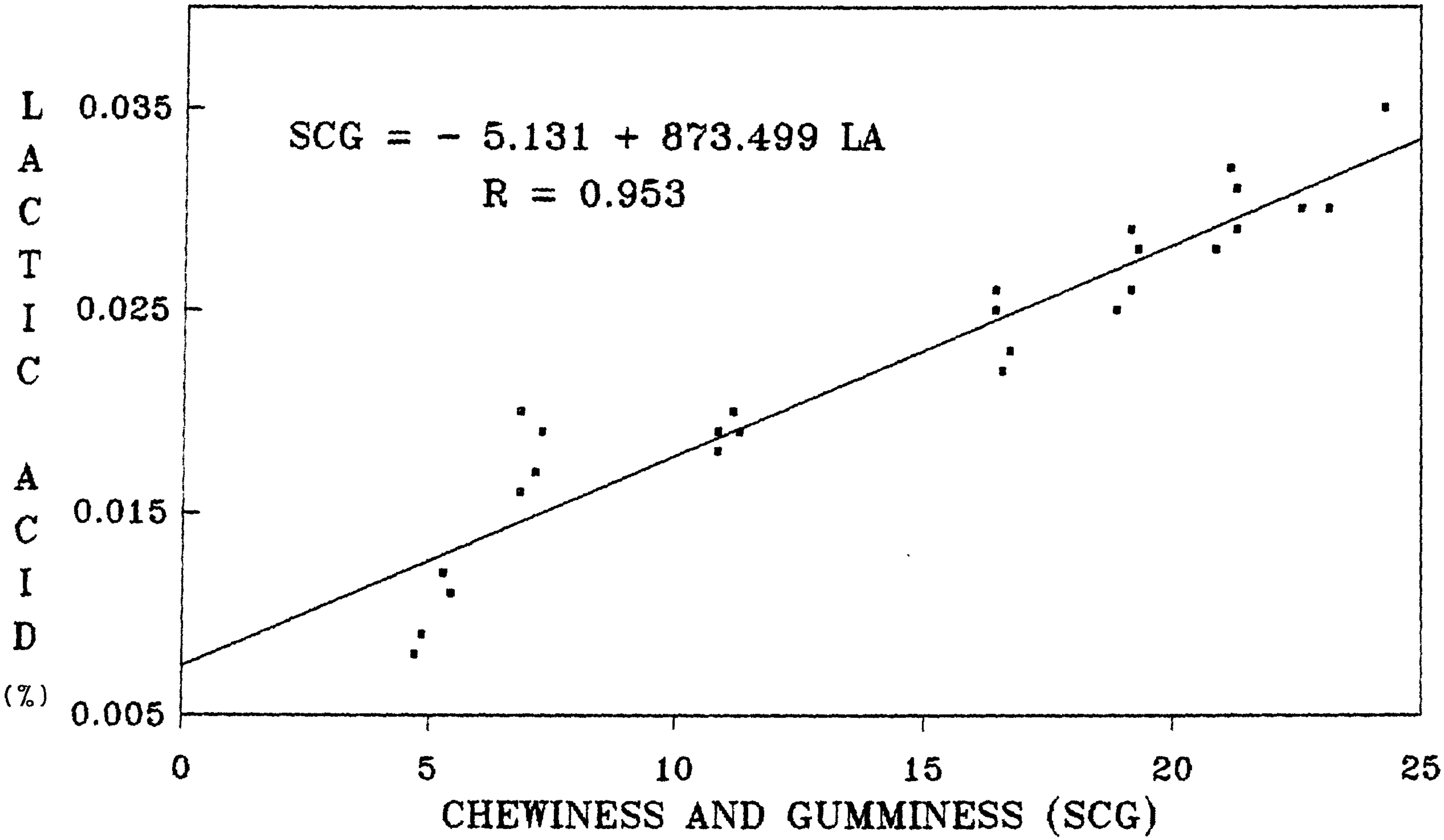

Fig. 42. Relationship between chewiness and gumminess scores and lactic acid at different days of drying

Table 34. Lactic acid (LA), FFA, TBA, titratable acidity (TA), total HMF (THMF) and tyrosine (Ty) individually explained 93, 98, 91, 89, 98 and 95% variation respectively in flavour score (Equations 1 - 6). Combined effect of TBA and THMF, and FFA and THMF explained 99% variation in flavour score (Equations7, 8). A cumulative effect of LA, TBA and TA explained 97%, whereas LA, FFA and THMF explained 99% variation in flavour (Equations 10, 11). Ninety-nine per cent variation in flavour score could be explained by all the intrinsic parameters taken together (Equation 16). THMF explained 99% variation in body and texture score, whereas only 84% by tyrosine (Equations 17, 18). A combined effect of TA and THMF explained 93% variability in colour and appearance score (Equation 22). Tyrosine, LA and THMF individually influenced 87%, 90% and 99% variability in sensory gumminess and chewiness (Equations 23 - 25). Cumulative effect of LA and TA explained 94% variation in total score (Equation 27).

4.6. Cost of production of churpi

The cost model described in Table 35 is developed on the basis of actual trials conducted under optimized process conditions.

The business of churpi production from cow milk is quite remunerative. It can be observed that conversion of 100 l cow milk per day into churpi will earn a net profit of about ₨ 6,637 per month with a total capital investment of ₨ 36,300 and the operating cost of ₨ 17,226 per month.

Table 34. Regression equations of sensory attributes as influenced by intrinsic parameters during drying of churpi

Sl No.	Equations*	Coefficient of correlation (R)**	Coefficient of determination (R^2)
1	$Fl = 6.799LA^{0.971}$	0.96	0.93
2	$Fl = 4.989TBA^{0.580}$	0.95	0.91
3	$Fl = 1.345+36.291FFA$	0.99	0.98
4	$Fl = 6.572TA^{2.510}$	0.94	0.89
5	$Fl = 18.513+0.825THMF$	0.99	0.98
6	$Fl = 6.309TY^{1.527}$	0.97	0.95
7	$Fl = 0.061FFA^{0.507}.THMF^{0.880}$	0.99	0.99
8	$Fl = 19.190-12.663TBA+0.849THMF$	0.99	0.99
9	$Fl = 3.985LA^{0.283}.TBA^{0.020}.FFA^{0.760}$	0.99	0.99
10	$Fl = 6.484LA^{0.506}.TBA^{0.159}.TA^{0.677}$	0.98	0.97
11	$Fl = 0.006LA^{0.013}.FFA^{0.498}.THMF^{0.875}$	0.99	0.99
12	$Fl = -0.337TA^{-0.097}.FFA^{0.522}.THMF^{0.918}$	0.99	0.99
13	$Fl = 4.634LA^{0.165}.TBA^{0.034}.FFA^{0.584}.TA^{0.335}$	0.99	0.98
14	$Fl = -0.357TA^{-0.099}.FFA^{0.524}.LA^{-0.003}.THMF^{0.920}$	0.99	0.99
15	$Fl = 0.216TY^{0.105}.FFA^{0.433}.LA^{0.021}.THMF^{0.876}$	0.99	0.99
16	$Fl = -0.293TA^{-0.127}.FFA^{0.496}.TBA^{0.024}LA^{0.004}.THMF^{0.916}$	0.99	0.99
17	$BT = 6.313TY^{1.656}$	0.91	0.84
18	$BT = -6.281THMF^{2.328}$	0.99	0.99
19	$CA = -6.337THMF^{2.047}$	0.96	0.93
20	$CA = 5.086TA^{2.466}$	0.88	0.78
21	$CA = 11.483TY^{-0.751}.THMF^{2.957}$	0.98	0.96

Sl No.	Equations*	Coefficient of correlation (R)**	Coefficient of determination (R^2)
22	$CA = -8.673TA^{-0.558}.THMF^{2.446}$	0.96	0.93
23	$SCG = -8.606THMF^{2.865}$	0.99	0.99
24	$SCG = -5.131+873.499LA$	0.95	0.90
25	$SCG = 6.994TY^{2.085}$	0.93	0.87
26	$SCG = 7.515TA^{3.544}$	0.94	0.87
27	$TS = 8.331LA^{0.603}.TA^{1.421}$	0.97	0.94

* Fl, Flavour
BT, Body and texture
CA, Colour and appearance
SCG, Chewiness and gumminess
TS, Total score
LA, Lactic acid
TBA, 2-Thiobarbituric acid
FFA, Free fatty acid
THMF, Total hydroxymethylfurfural
TY, Tyrosine

** Significant at P<0.001

Table 35. Cost of production of churpi

1. Inputs	
100 l cow milk of 3.5% fat and 8.7% SNF per day	3000 l milk per month
2. Variable cost (for one month)	Amount (Rs)
2.1. Raw materials and utilities:	
Milk 3,000 l @ Rs 4/l	12,000
Markin cloth 10 m @ Rs 10/m	100
Citric acid 7.0 kg @ Rs 70/kg	490
Steam 700 kg @ Re 0.75/kg	525
Water 18,000 l @ Re 1.0/1000 l	18
Electricity 100 kw @ Re 1.0/kw	100
Skilled labour 1 @ Rs 25/day	750
Unskilled labour 1 @ Rs 20/day	600
Quality control expenses	200
Miscellaneous expenses	50
Packaging expenses	500
	15,333
2.2. Building rent @ Rs 750/month	750
Total	16,083
3. Fixed cost	
Aluminium milk cans 6 @ Rs 800/can	4,800
Cream separator	3,000
Mini boiler/50 kg/h water evaporation capacity	20,000
Heating vessel/250 l capacity @ Rs 5000 each	5,000
Weighing balance 1	1,500
Laboratory equipment	2,000
Total	36,300

	Amount (Rs)
4. Depreciation on fixed cost @ 10% per annum for one month	303
5. Interest on capital investment @ 18% per annum for one month	545
6. Interest on running expenses for one month @ 22% per annum	295
	1,143
Variable cost	16,083
Total expenditure:	17,226

7. Output

Yield of churpi 4.13 kg per 100 kg of milk, total churpi 123.9 kg @ Rs 125/kg	15,488
Surplus fat 2.5 kg per day converted into ghee, 95% recovery i.e. 71.25 kg @ Rs 100/kg	7,125
Sale of 2,500 l of whey @ Re 0.50/l	1,250
Total:	23,863

8. Net profit

Rs 23,863 - 17,226 = Rs 6,637 per month or Rs 221 per day

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.

6. SUMMARY

Churpi, a popular chewing gum, is traditionally produced from yak, joo and cow milk in Bhutan, Sikkim and Darjeeling, respectively.

The churpi prepared and marketed in Bhutan had least moisture, fat, water-dispersible protein (WDP), titratable acidity, pH and energy value than the churpi of two other places. On the other hand, the values of these parameters are maximum in the churpi of Darjeeling.

The churpi prepared in Darjeeling containing higher lactic acid, free fatty acid (FFA), 2-thiobarbituric acid (TBA), tyrosine and reflectance was less acceptable by the judges with respect to all the sensory attributes, and criticized as having rancid flavour and weak body. Significantly poor sensory scores of churpi prepared in Darjeeling might apparently be due to less heat treatment of green curd which resulted in higher fat, protein and lactose hydrolysis. On the other hand, the churpi prepared in Bhutan was rated highest with respect to all the sensory attributes, and graded as the best quality market samples.

The churpi prepared in Bhutan containing high elastcity, firmness, smoothness, gumminess and chewiness but less crumbliness was rated most desirable with respect to overall textural quality. The churpi prepared in Bhutan also exhibited greater hardness, cohesiveness, springiness, gumminess and chewiness on instrumental analysis than the churpi prepared in Sikkim and Darjeeling.

Lactic acid, free HMF, tyrosine and p-dimethylaminobenzaldehyde combinedly reflected 86% variation in total scores of market churpi, which is a better prediction than the effect of any single intrinsic parameters.

Instron parameters were greatly influenced by the chemical composition of churpi. WDP alone explained 54% variation in hardness, 78% variation in cohesiveness, 80% variation in gumminess and 74% variation in chewiness. All the instron parameters taken together explained 72% variation of the overall sensory texture scores of churpi.

The present study has shown that to get a good quality churpi from cow milk it is necessary to standardize milk to 1.0% fat and 8.7% solids-not-fat, heating milk to 70°C, coagulating milk within 60 s with hot (70°C) 2.0% citric acid solution, removing coagulum immediately from whey without any holding by filtering through a muslin cloth, cooking of green curd in a boiling water bath for 20 min, wrapping hot cooked mass in muslin cloth, pressing it at 9 $kg.cm^{-2}$ for 12 h and drying over wooden fire for 40-50 days at 30 ± 5°C.

Out of 200 respondents, 98 preferred the laboratory-made churpi over market churpi. Of them, 46% indicated better flavour as the reason for their preference.

Flavour, body and texture, gumminess and chewiness and total sensory scores increased significantly ($P<0.001$) at every 7 days intervals from initiation to end of drying.

Moisture content decreased from initial 46% to 13% at maturity. Titratable acidity increased from 0.19% to 0.28% on 28th day and no further increase was observed. Increase in lactic acid was moderate after 7 days. The FFA increased from initial 0.22% to 0.86% at maturity. Free and total 5-hydroxymethylfurfural showed a steady increase till the end of drying. The increase in FFA and TBA during manufacturing churpi could be due to hydrolysis of fat and formation of saturated and unsaturated aldehydes. Minimum degradation of protein which is evident from low tyrosine content (0.15 mg/g) resulted in characteristic hard body of churpi.

The flavour score was influenced by 99% with all the intrinsic parameters taken together.

Calculated data on cost of production of churpi showed that conversion of 100 l cow milk per day into churpi will earn a net profit of Rs 6,637 per month with a total capital investment of Rs 36,300 and the operating cost of Rs 17,226 per month.

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