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] (30.0-34.0)	29.60[b] (26.0-33.0)	19.75[c] (13.0-25.0)
Body and texture	28.05[a] (27.0-29.0)	25.75[a] (23.0-28.0)	18.85[b] (13.0-22.0)
Colour and appearance	8.30[a] (8.0-9.0)	6.80[b] (5.0-7.0)	6.15[b] (5.0-8.0)
Gumminess and chewiness	23.45[a] (21.0-24.0)	21.00[b] (19.0-22.0)	17.45[c] (15.0-19.0)
Total score	92.80[a] (88.0-96.0)	83.15[b] (77.0-87.0)	62.20[c] (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]	72.80[a]	36.95[b]
	(60.00-90.00)	(58.00-92.00)	(26.00-52.00)
Firmness	76.90[a]	71.85[a]	42.70[b]
	(70.00-90.00)	(68.00-82.00)	(39.00-52.00)
Crumbliness	19.30[c]	41.90[b]	74.50[a]
	(7.00-38.00)	(20.00-61.00)	(59.00-85.00)
Smoothness	78.50[a]	63.30[a]	39.90[b]
	(51.00-92.00)	(43.00-84.00)	(20.00-68.00)
Gumminess	82.35[a]	64.95[b]	30.95[c]
	(61.00-92.00)	(40.00-76.00)	(7.00-51.00)
Chewiness	76.50[a]	69.95[a]	35.85[b]
	(61.00-88.00)	(59.00-85.00)	(21.00-56.00)
Overall textural quality	77.50[a]	72.65[a]	36.95[b]
	(61.00-89.00)	(60.00-92.00)	(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 ($P<0.05$).

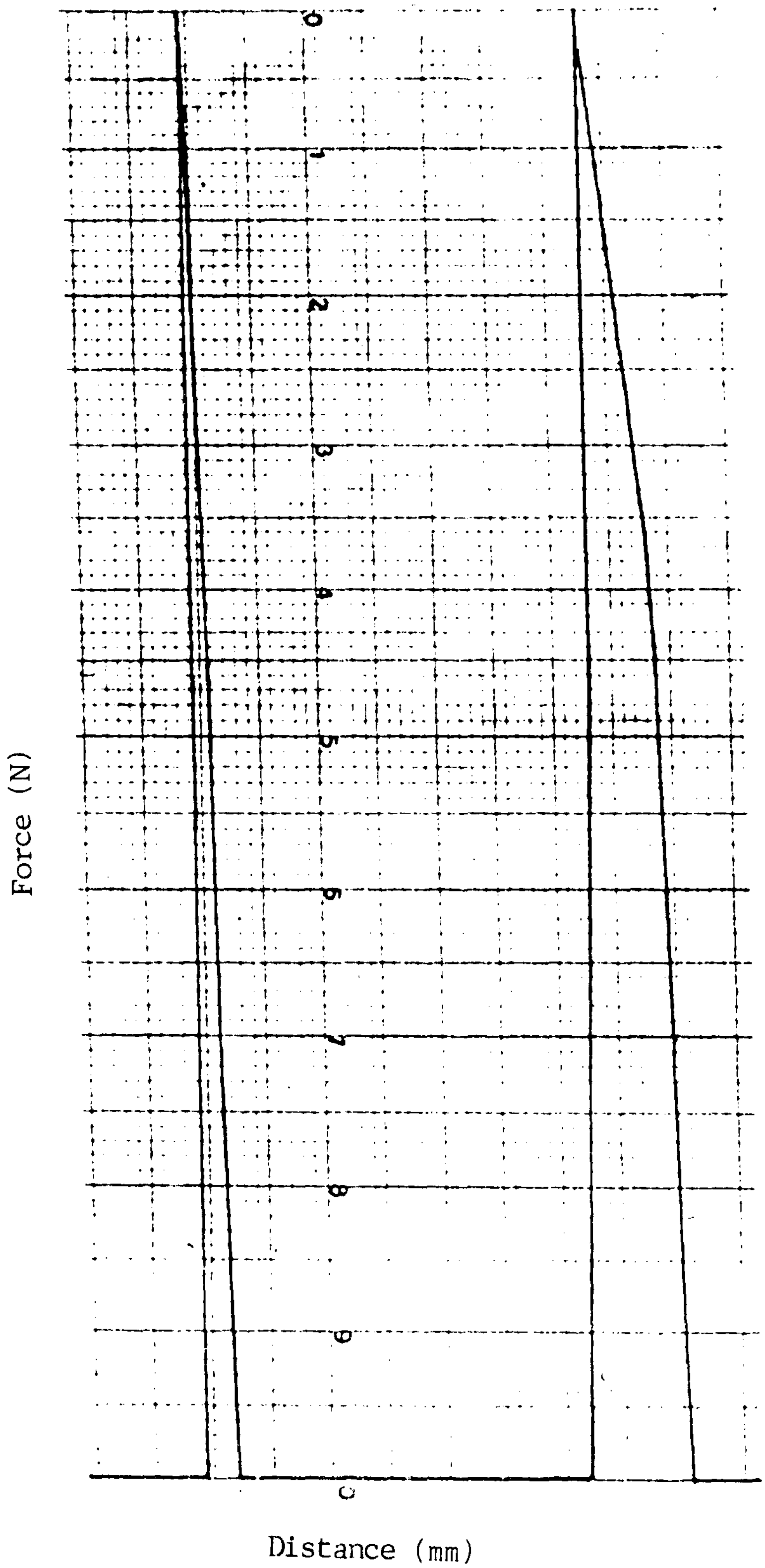


Fig. 12. Texture profile curve for churpi

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	$GCh = 1.893THMF^{0.288}$	0.729***	0.532
24	$GCh = 2.727TY^{-0.186}$	0.760***	0.578
25	$GCh = 3.579pDMAB^{0.319}$	0.659***	0.434
26	$GCh = 2.611TY^{-0.099}.FHMF^{0.086}$	0.795***	0.632
27	$GCh = 2.297TY^{-0.118}.THMF^{0.137}$	0.789***	0.623
28	$GCh = 23.512-13.281LA-6.207TY$	0.824***	0.679
29	$GCh = 24.39-14.509LA-6.585TY-0.012THMF$	0.825***	0.681
30	$TS = 3.892LA^{-0.164}$	0.891***	0.794
31	$TS = 2.749THMF^{0.412}$	0.836***	0.699
32	$TS = 4.435FFA^{-0.274}$	0.822***	0.675
33	$TS = 3.954TY$	0.846***	0.715
34	$TS = 3.584LA^{-0.129}.THMF^{0.104}$	0.896***	0.804
35	$TS = 4.055LA^{-0.077}.THMF^{0.025}.TY^{-0.106}.pDMAB^{0.103}$	0.919***	0.844
36	$TS = 3.971LA^{-0.046}.FHMF^{0.084}.TY^{-0.088}.pDMAB^{0.071}$	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	0.727	0.520	0.728	0.705
	(0.584)	(0.757)	(0.514)	(0.756)	(0.723)
Total fat	-0.589	-0.623	-0.531	-0.631	-0.599
	(-0.556)	(-0.684)	(-0.499)	(-0.704)	(-0.682)
Free fat	-0.496	-0.613	-0.394**	-0.615	-0.592
	(-0.455)	(-0.611)	(-0.369)**	(-0.614)	(-0.568)
Total protein	0.513	0.577	0.519	0.594	0.608
	(0.474)	(0.596)	(0.452)	(0.606)	(0.596)
Water-dispersible protein	-0.736	-0.807	-0.563	-0.813	-0.786
	(-0.700)	(-0.883)	(-0.598)	(-0.891)	(-0.861)
Titratable acidity	-0.684	-0.731	-0.648	-0.742	-0.704
	(-0.689)	(-0.857)	(-0.626)	(-0.877)	(-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	-0.635	0.724	0.668	0.582	0.741	0.724
	(0.579)	(-0.537)	(0.751)	(0.679)	(0.448)	(0.750)	(0.750)
Cohesiveness	0.734	-0.753	0.718	0.717	0.813	0.751	0.723
	(0.777)	(-0.723)	(0.789)	(0.689)	(0.763)	(0.798)	(0.791)
Springiness	0.465	-0.571	0.610	0.588	0.540	0.591	0.607
	(0.418)	(-0.470)	(0.637)	(0.591)	(0.413)**	(0.603)	(0.635)
Gumminess	0.739	-0.763	0.726	0.730	0.816	0.755	0.730
	(0.778)	(-0.724)	(0.829)	(0.724)	(0.740)	(0.836)	(0.831)
Chewiness	0.688	-0.752	0.670	0.733	0.793	0.748	0.701
	(0.699)	(-0.683)	(0.823)	(0.733)	(0.670)	(0.813)	(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 textı 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	$SCh = 4.325Spr^{0.495}$	0.60	0.36
25	$SCh = 2.672Ch^{0.274}$	0.81	0.66
26	$SCh = -7.427H^{1.682}.Spr^{-0.195}$	0.76	0.58
27	$SCh = -2.142H^{0.861}.C^{0.333}.Spr^{-0.136}$	0.86	0.73
28	$OTQ = -4.631H^{1.288}$	0.75	0.56
29	$OTQ = 4.633C^{0.488}$	0.79	0.63
30	$OTQ = -0.242H^{0.694}.C^{0.323}$	0.85	0.72
31	$OTQ = 2.144G^{0.243}.Ch^{0.114}$	0.84	0.70
32	$OTQ = 1.861C^{-0.046}.G^{0.295}.Ch^{0.102}$	0.84	0.70
33	$OTQ = -0.667H^{0.673}.C^{0.245}.Spr^{13.298}.G^{183.397}.Ch^{-183.315}$	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	458.90^{d}	557.23^{c}	976.75^{a}	999.80^{a}	886.50^{b}
(N)	(450.37-470.85)	(550.30-564.30)	(925.00-996.00)	(994.40-1010.00)	(884.00-890.40)
Cohesiveness	0.26^{bc}	0.19^{c}	0.23^{bc}	0.76^{a}	0.30^{b}
	(0.23-0.30)	(0.17-0.22)	(0.20-0.25)	(0.70-0.83)	(0.29-0.31)
Springiness	1.25^{b}	1.60^{a}	1.08^{b}	0.66^{c}	1.20^{b}
(mm)	(1.00-1.40)	(1.40-1.80)	(1.00-1.20)	(0.60-0.80)	(1.20-1.20)
Gumminess	120.60^{c}	105.88^{c}	222.02^{b}	760.12^{a}	261.52^{b}
(N)	(104.15-141.25)	(93.55-121.90)	(198.16-248.80)	(696.08-838.30)	(247.86-274.04)
Chewiness	152.66^{c}	168.72^{c}	238.60^{bc}	502.92^{a}	313.82^{b}
(N.mm)	(104.15-197.76)	(150.10-195.04)	(198.16-266.40)	(417.65-597.90)	(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

	Coagulation temperature (°C)				
Attributes	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

Attributes	Holding time in whey (min)			
	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

	Citric acid						
Strength (%)	pH	Titratable acidity (%)	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

	Coagulants			
Instron parameters	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 $MR = 2.097 - 0.039El + 0.003El^2$.

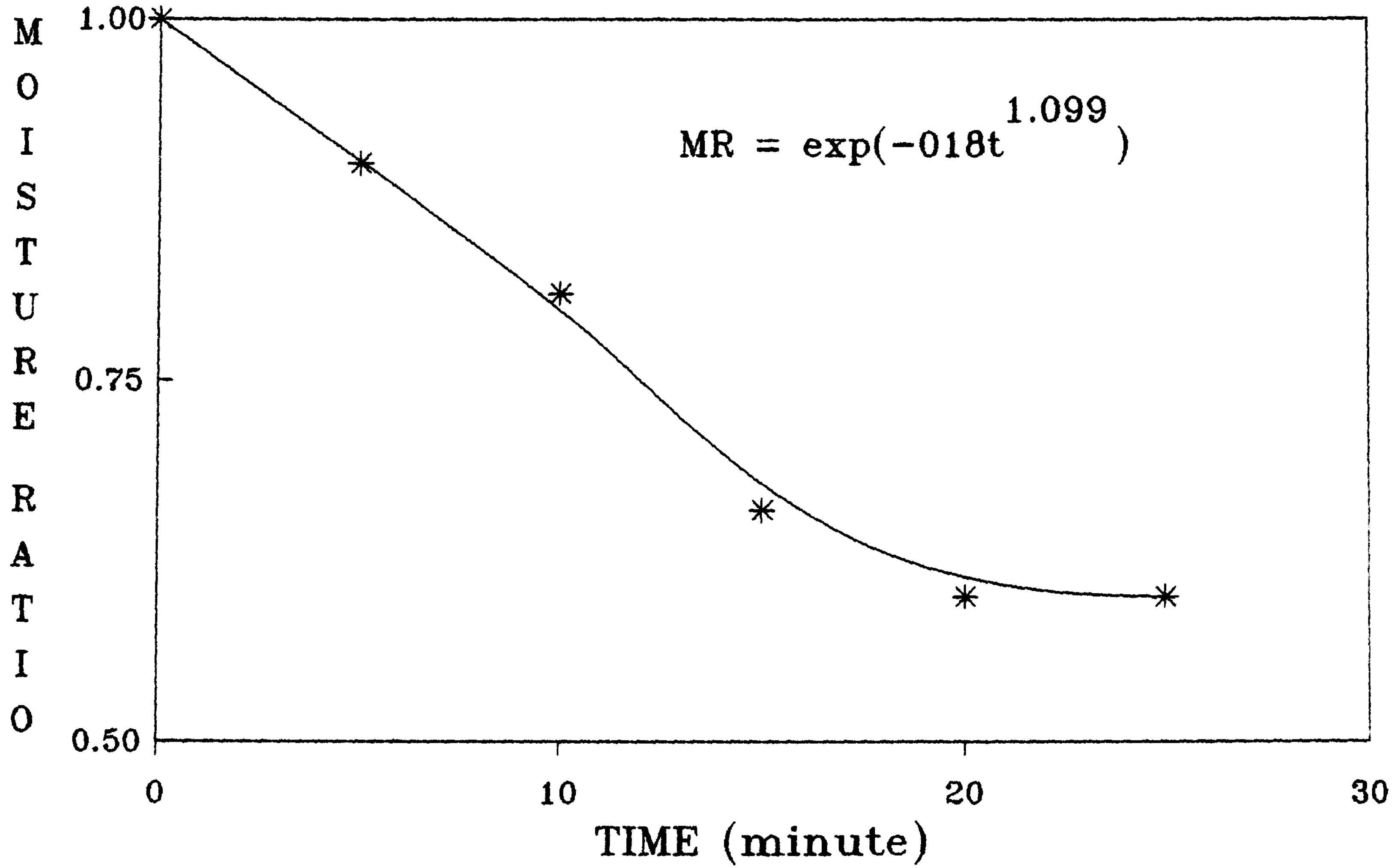


Fig. 13. Effect of time of cooking on moisture ratio (MR)

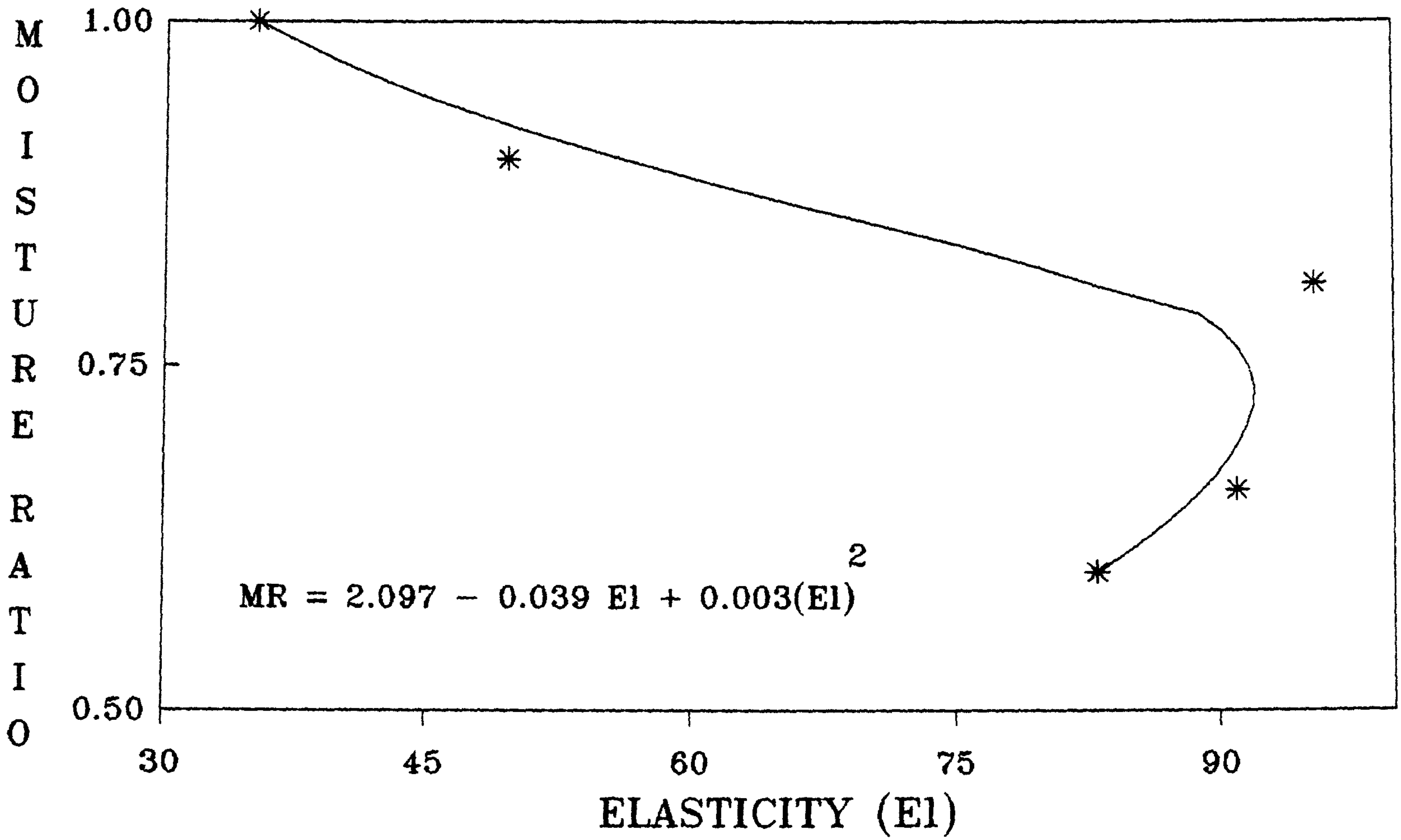


Fig. 14.Effect of elasicity(El) on moisture ratio(MR) at different interval of cooking

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:

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

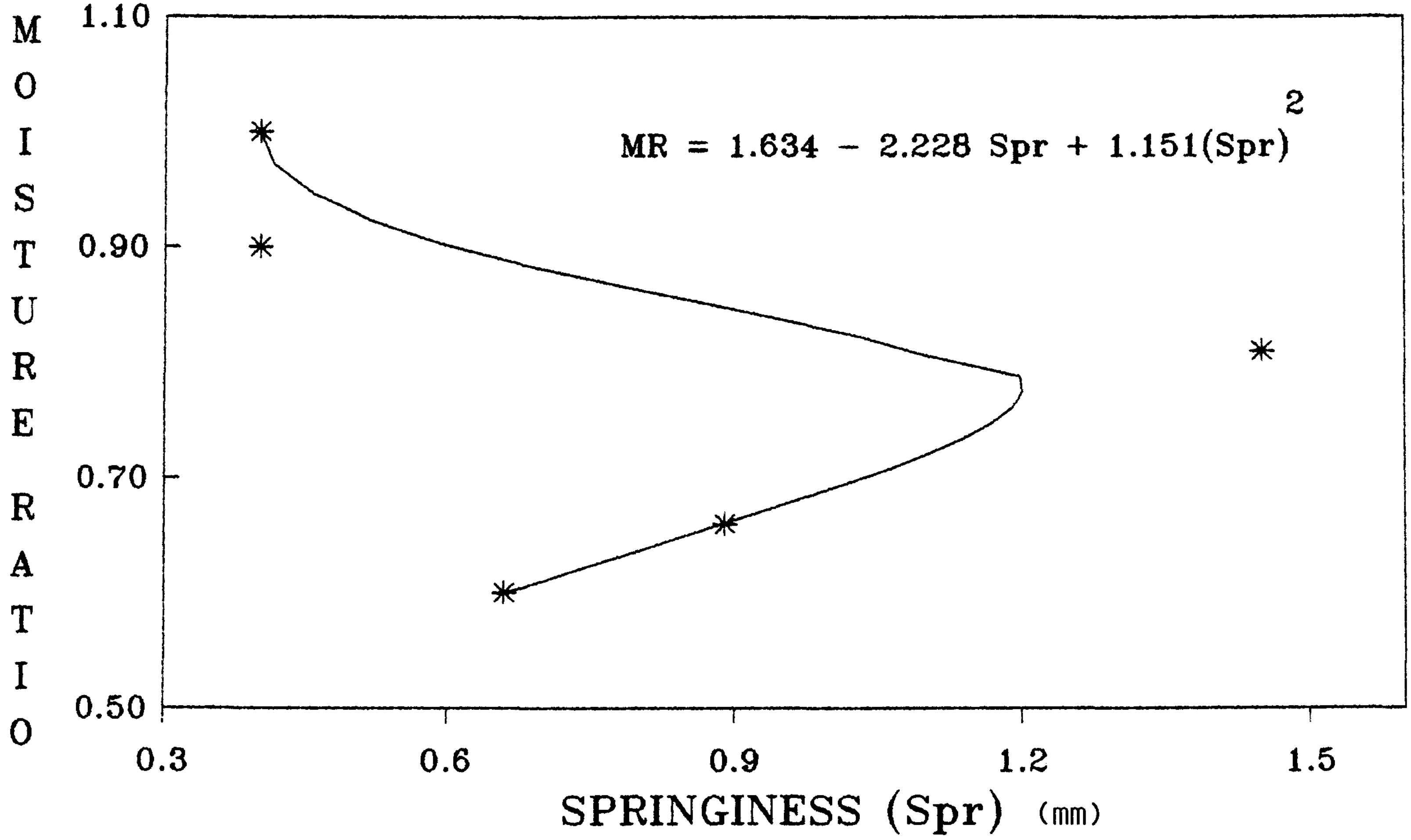


Fig. 15 . Effect of springiness(Spr) on moisture ratio(MR) at different interval of cooking

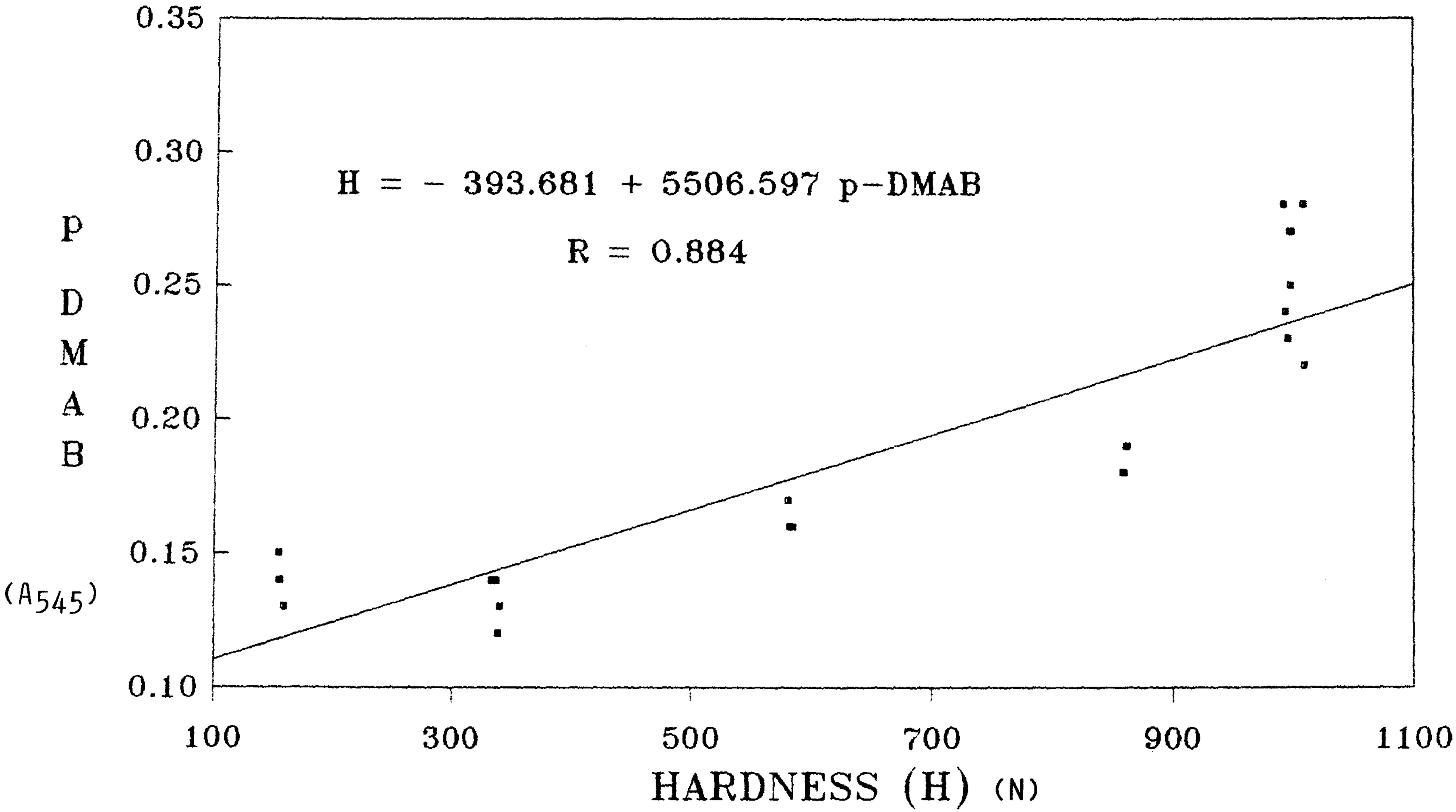


Fig. 16 . Relationship between hardness(H) and p-DMAB reactivity at different interval of cooking

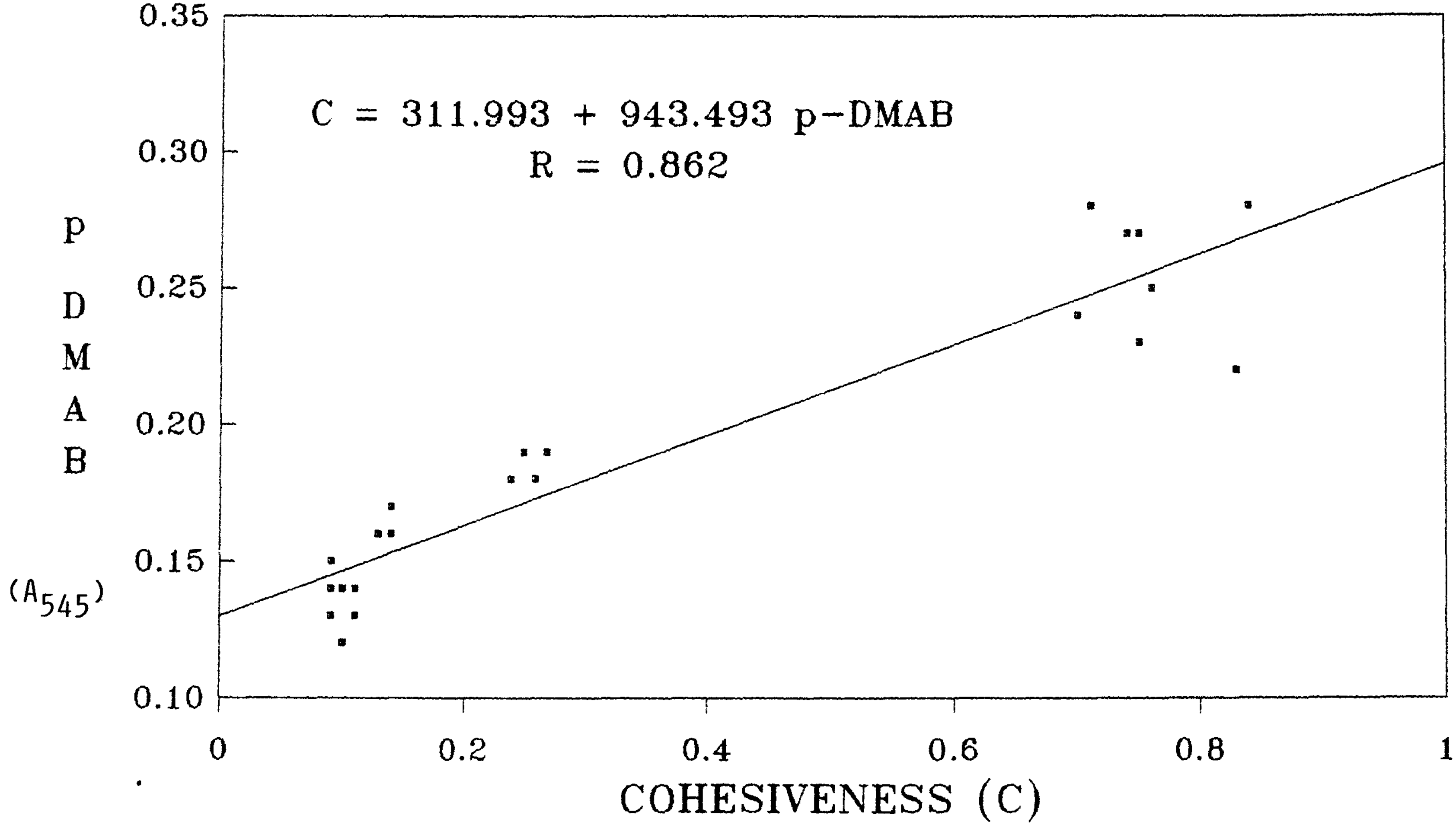


Fig. 17 .Relationship between cohesiveness(C) and p-DMAB reactivity at different interval of cooking

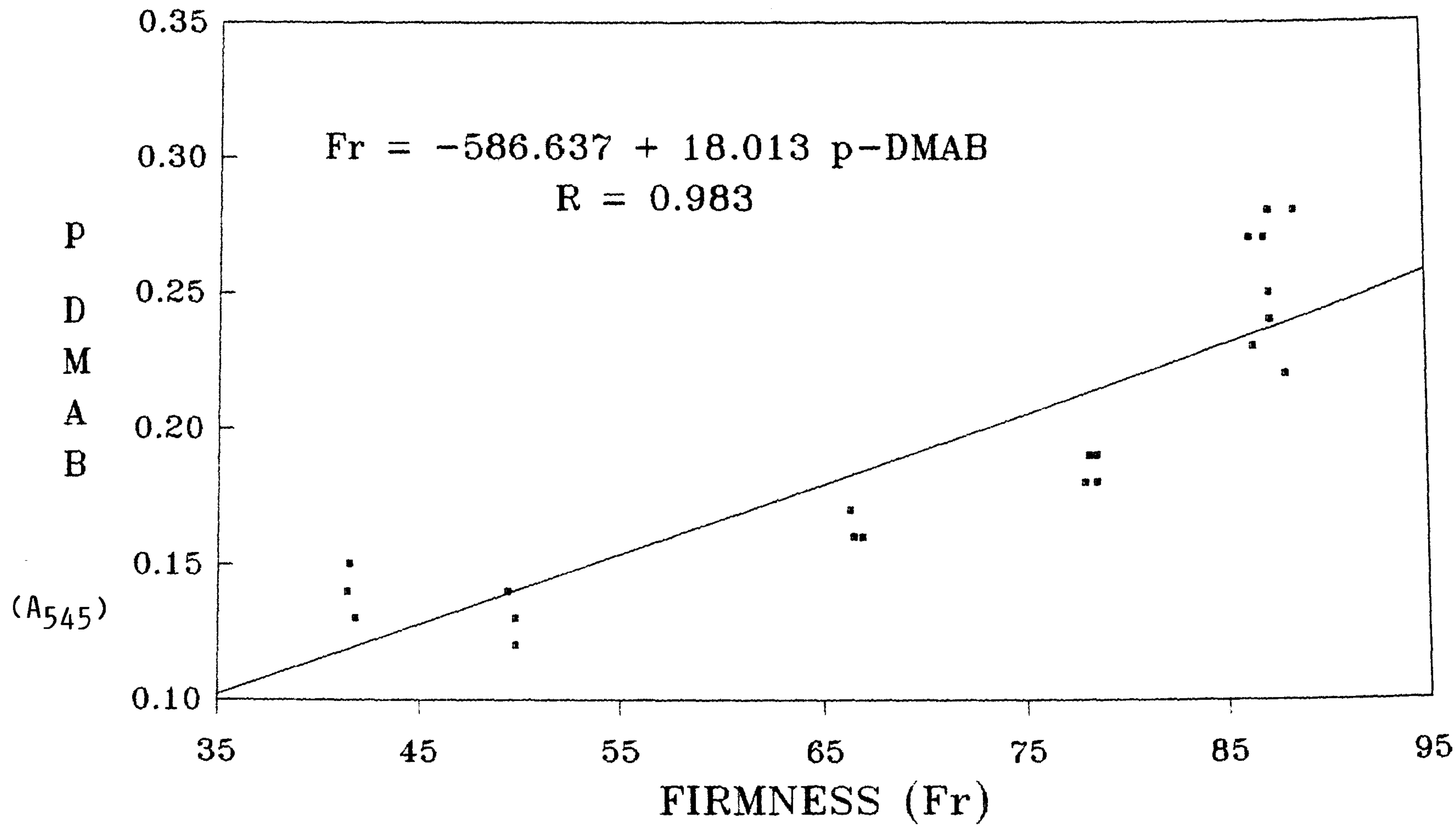


Fig. 18 . Relationship between firmness (Fr) and p−DMAB reactivity at different interval of cooking

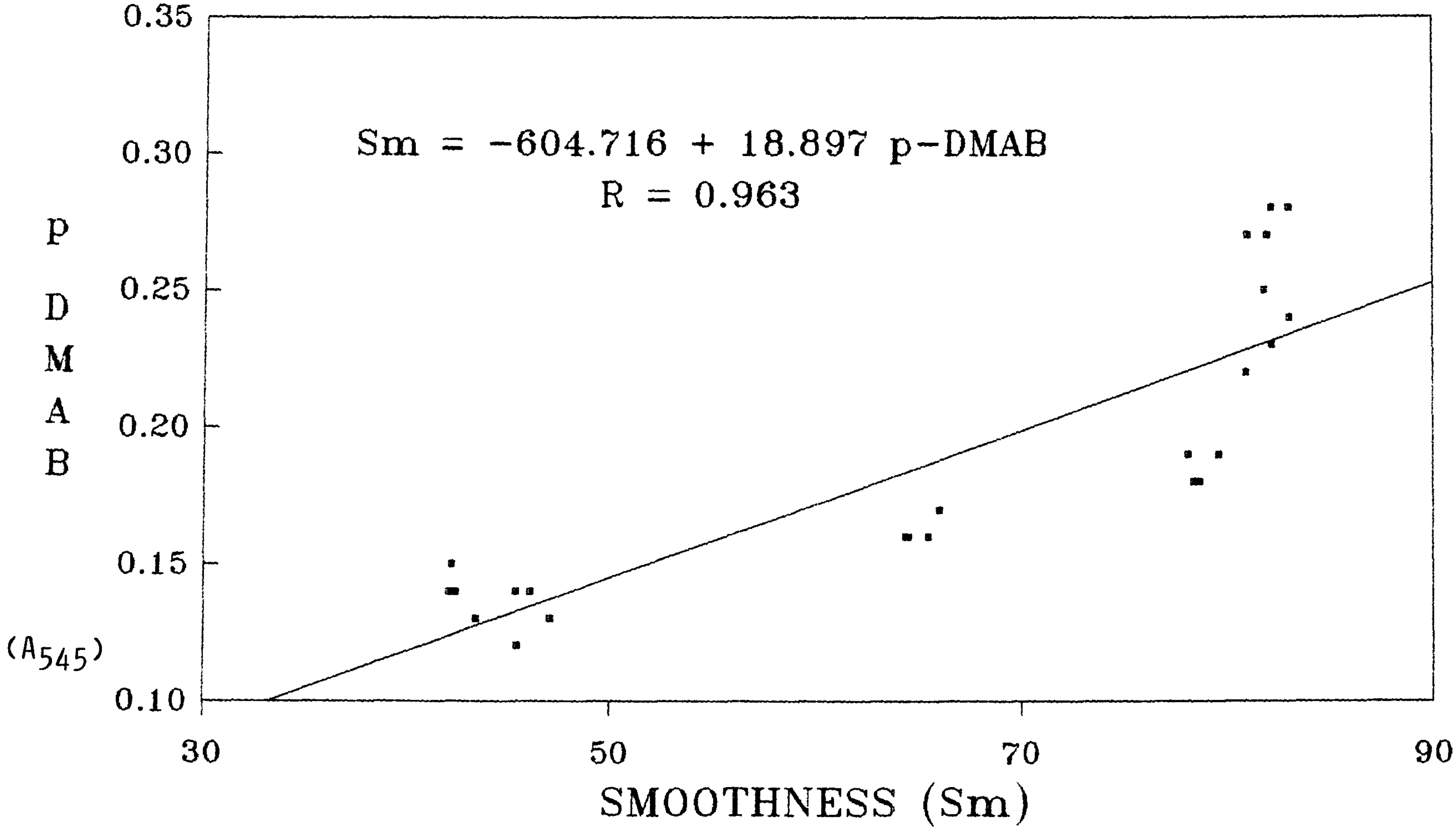


Fig. 19 . Relationship between smoothness(Sm) and p-DMAB reactivity at different interval of cooking

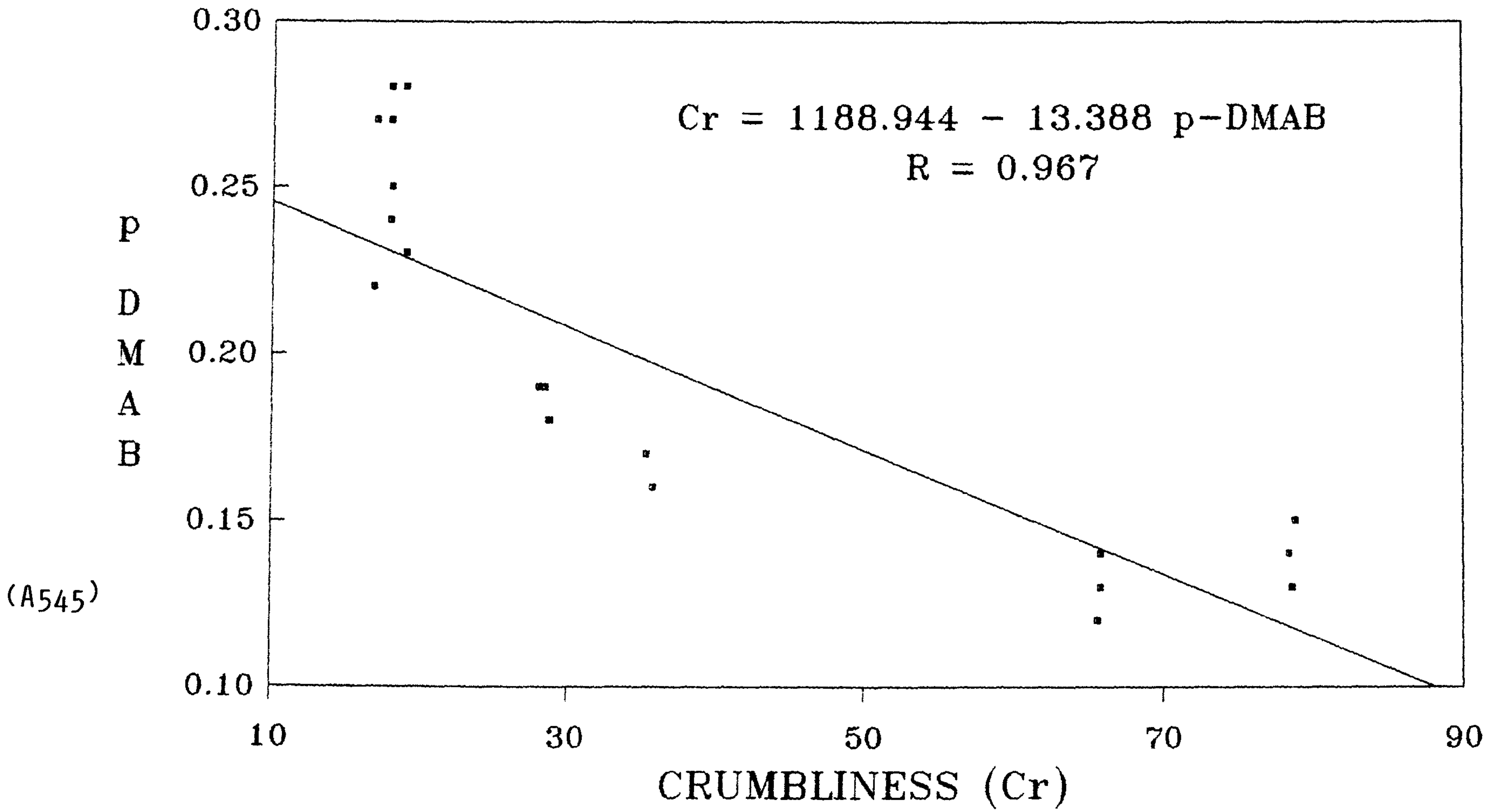


Fig. 20. Relationship between crumbliness(Cr) and p-DMAB reactivity at different interval of cooking

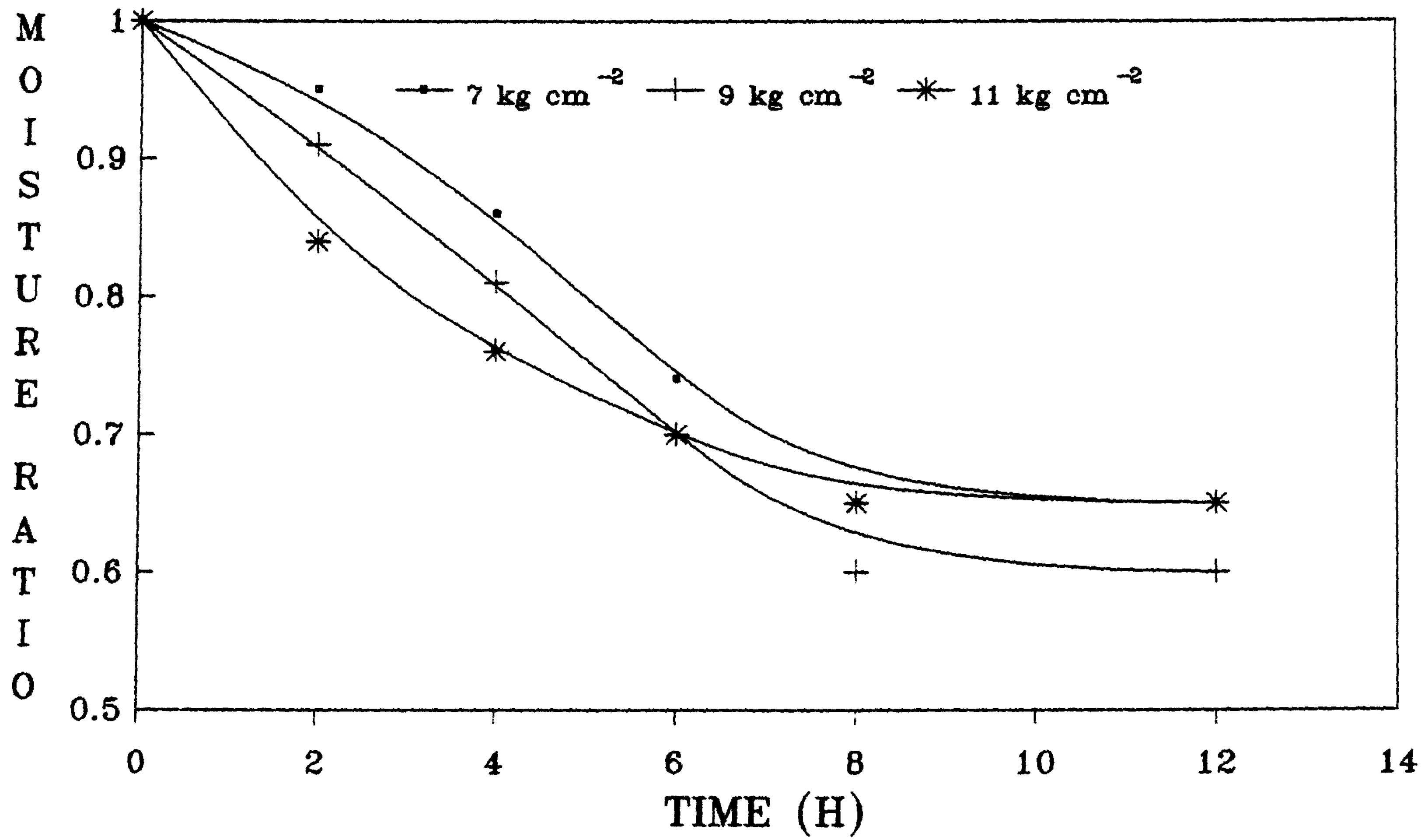


Fig. 21 ·Effect of time of pressing on moisture ratio (MR)

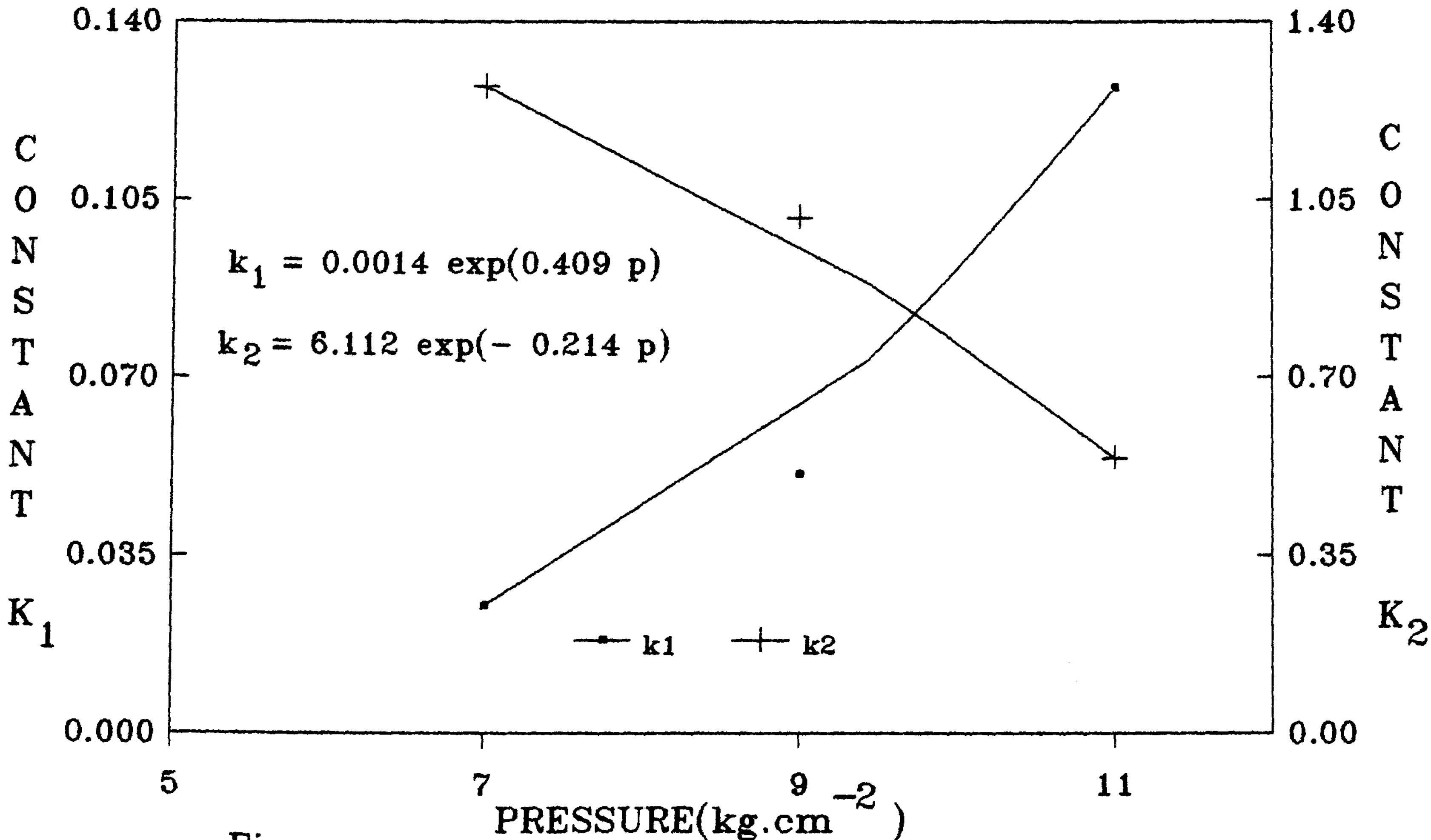


Fig. 22 ·Effect of pressure on constants k_1 and k_2

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:

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

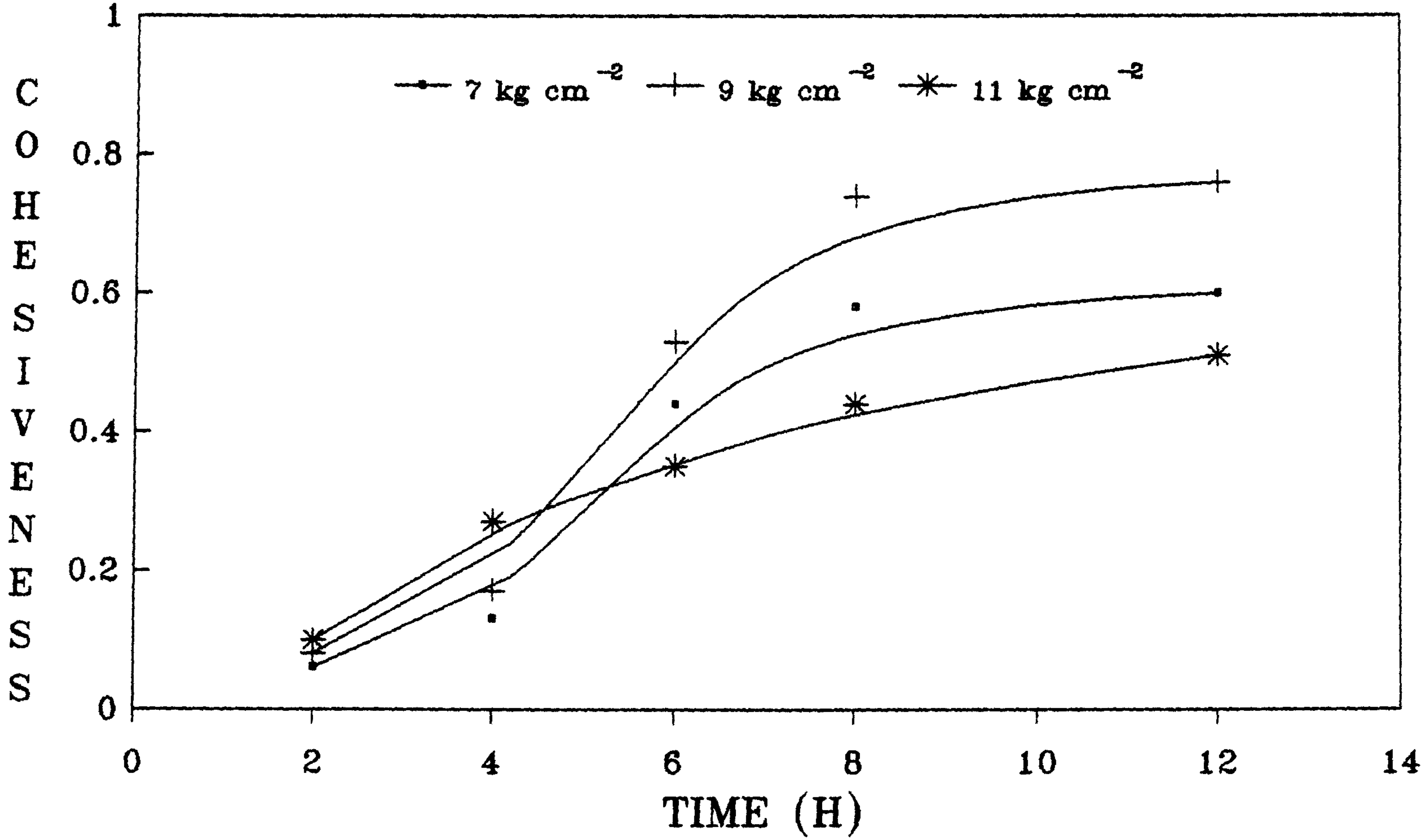


Fig. 23 ·Effect of time of pressing on cohesiveness (C)

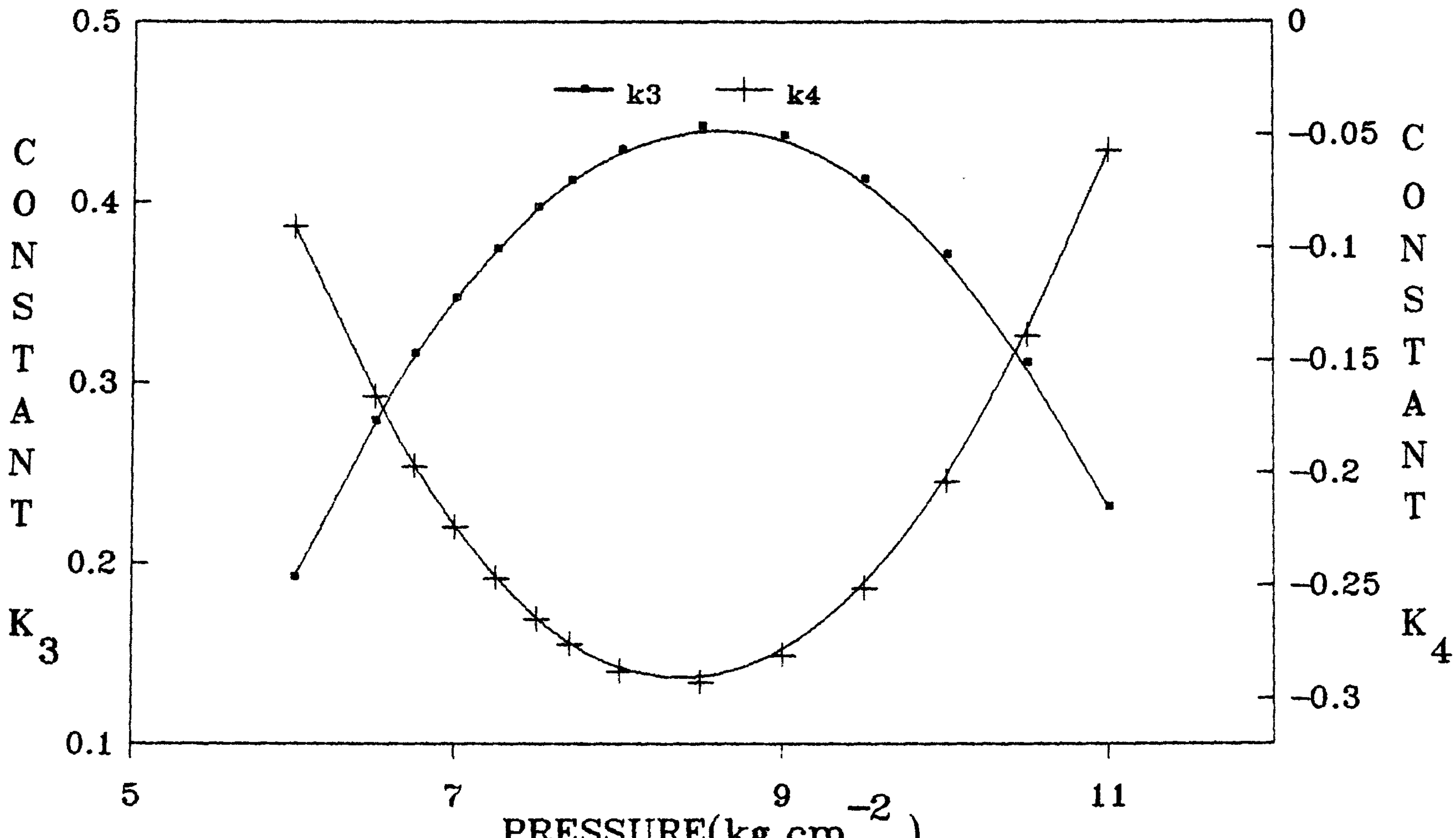


Fig. 24 . Effect of pressure on constants K_3 and K_4

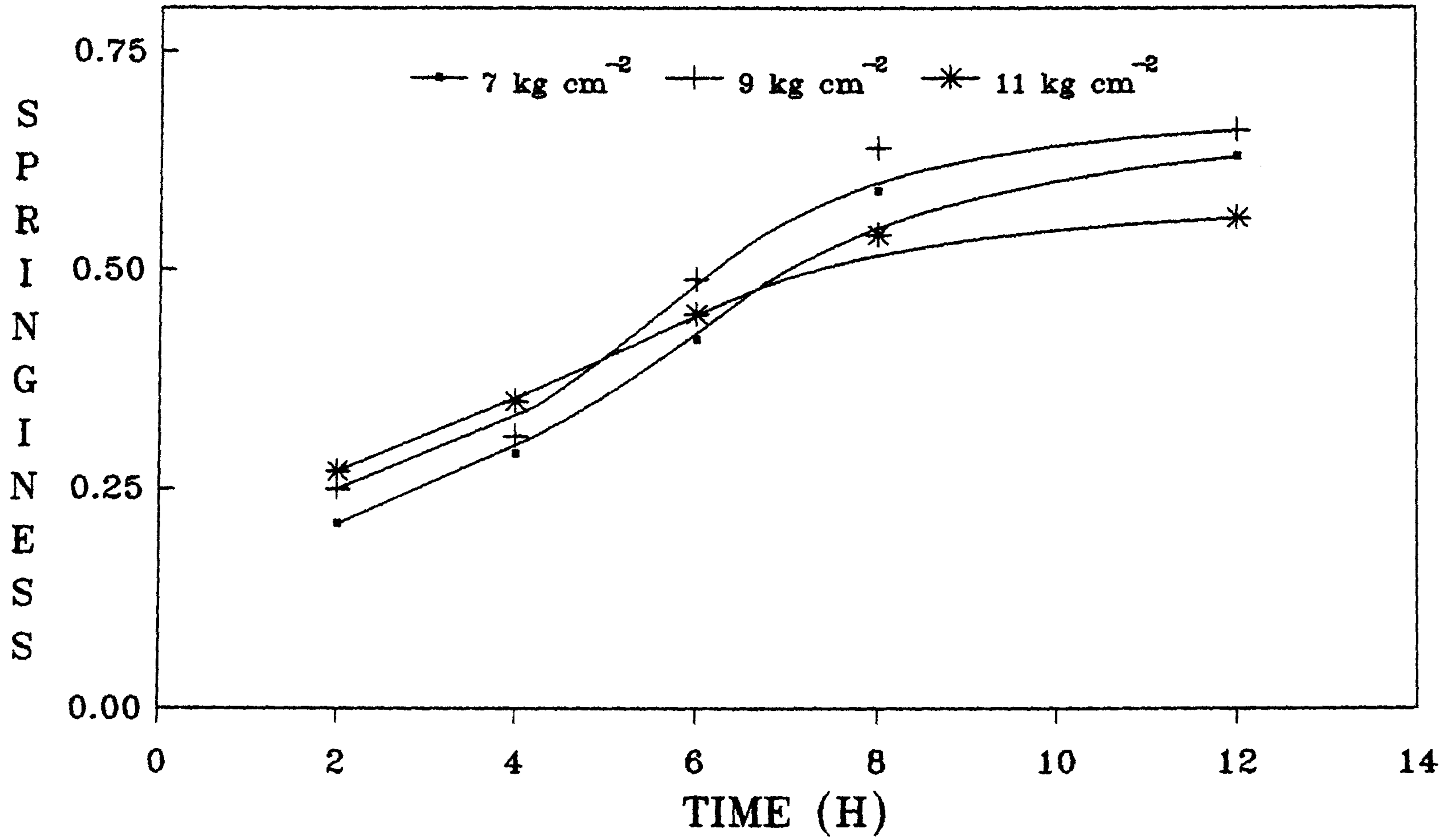


Fig. 25 . Effect of time of pressing on springiness (mm)

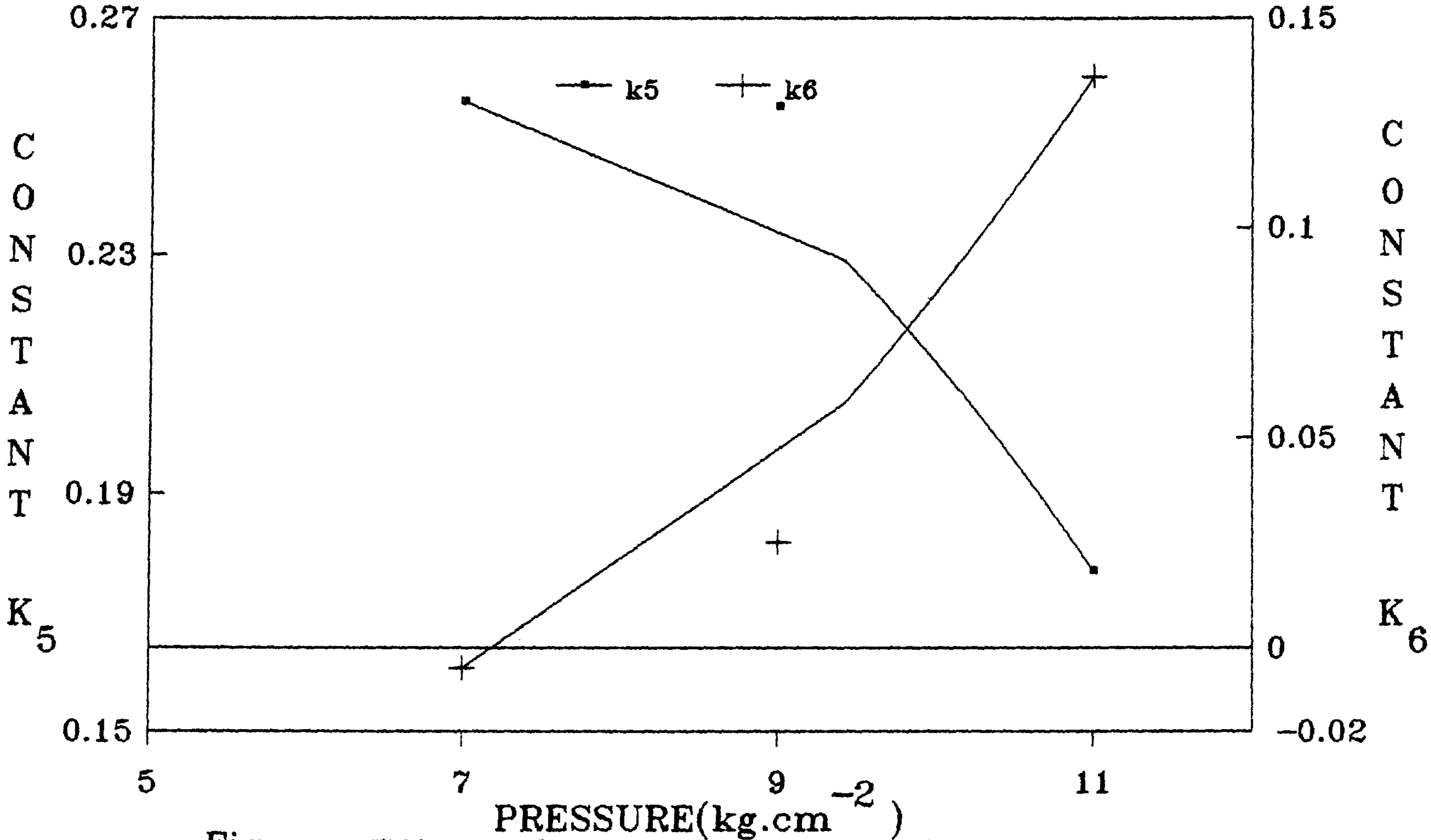


Fig. 26 · Effect of pressure on constants k5 and k6

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

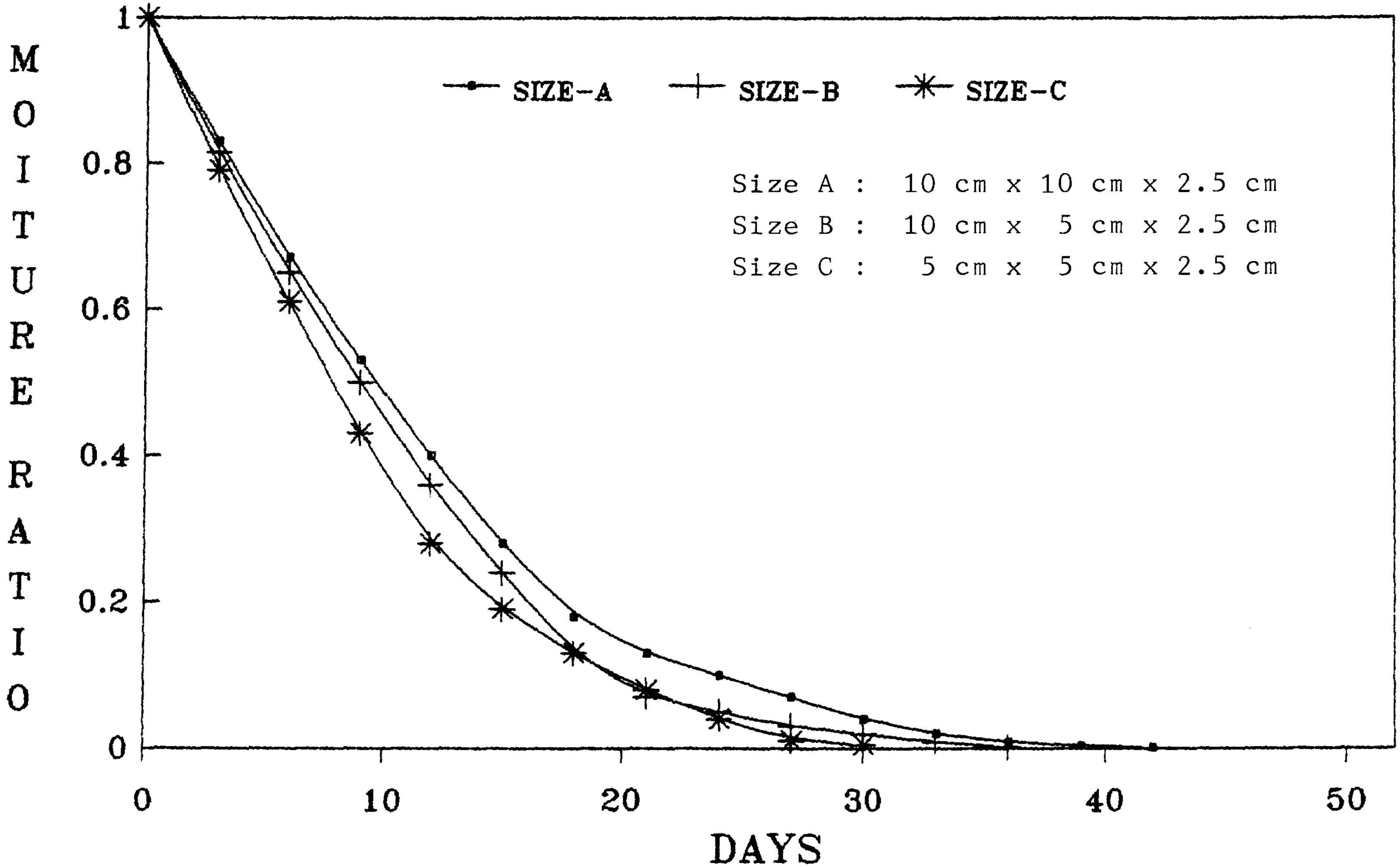


Fig. 27 . Drying behaviour as effected by size of churpi

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

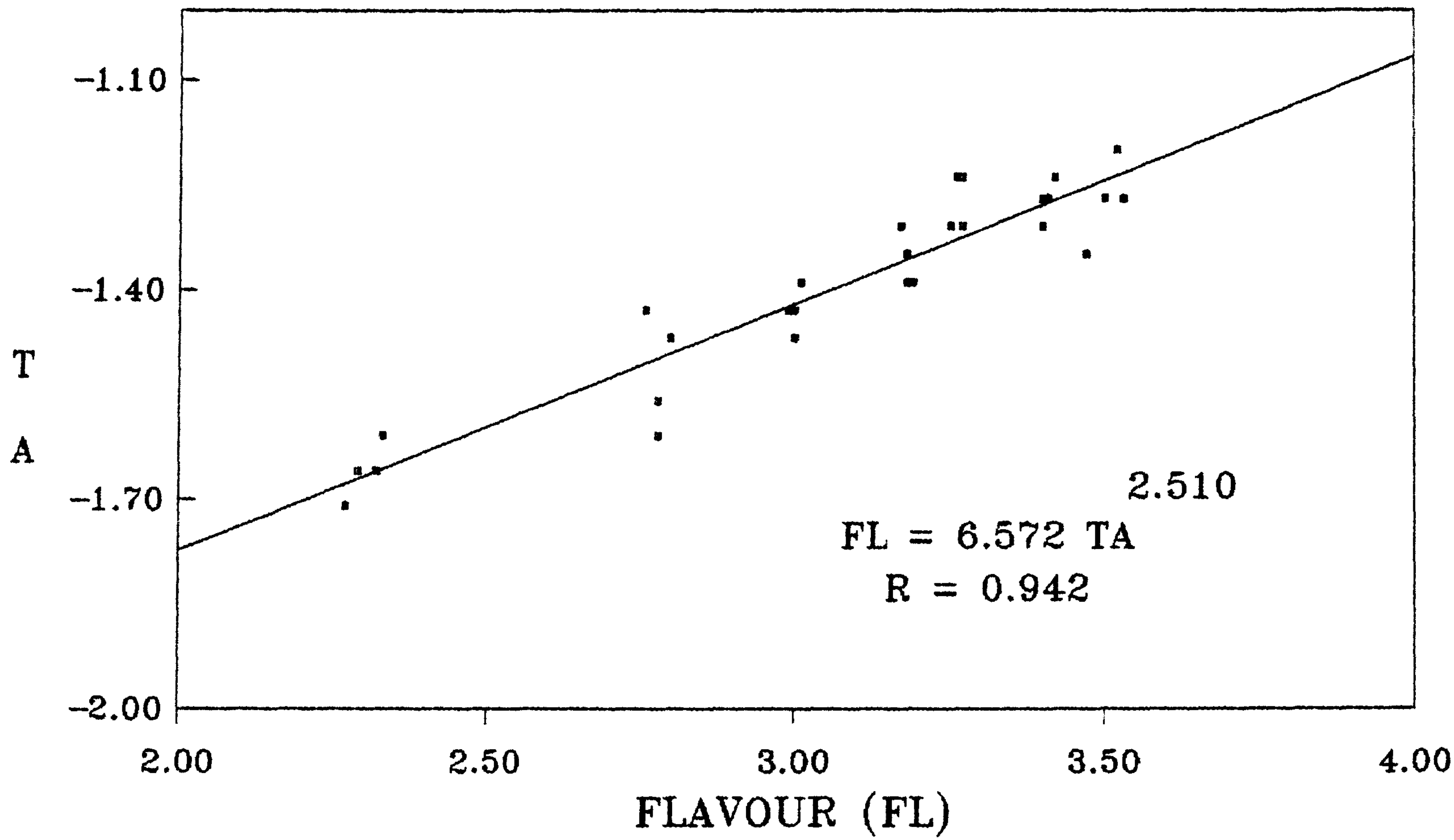


Fig. 28 . Relationship between flavour(FL) scores and titratable acidity (TA%) of churpi at different days of drying

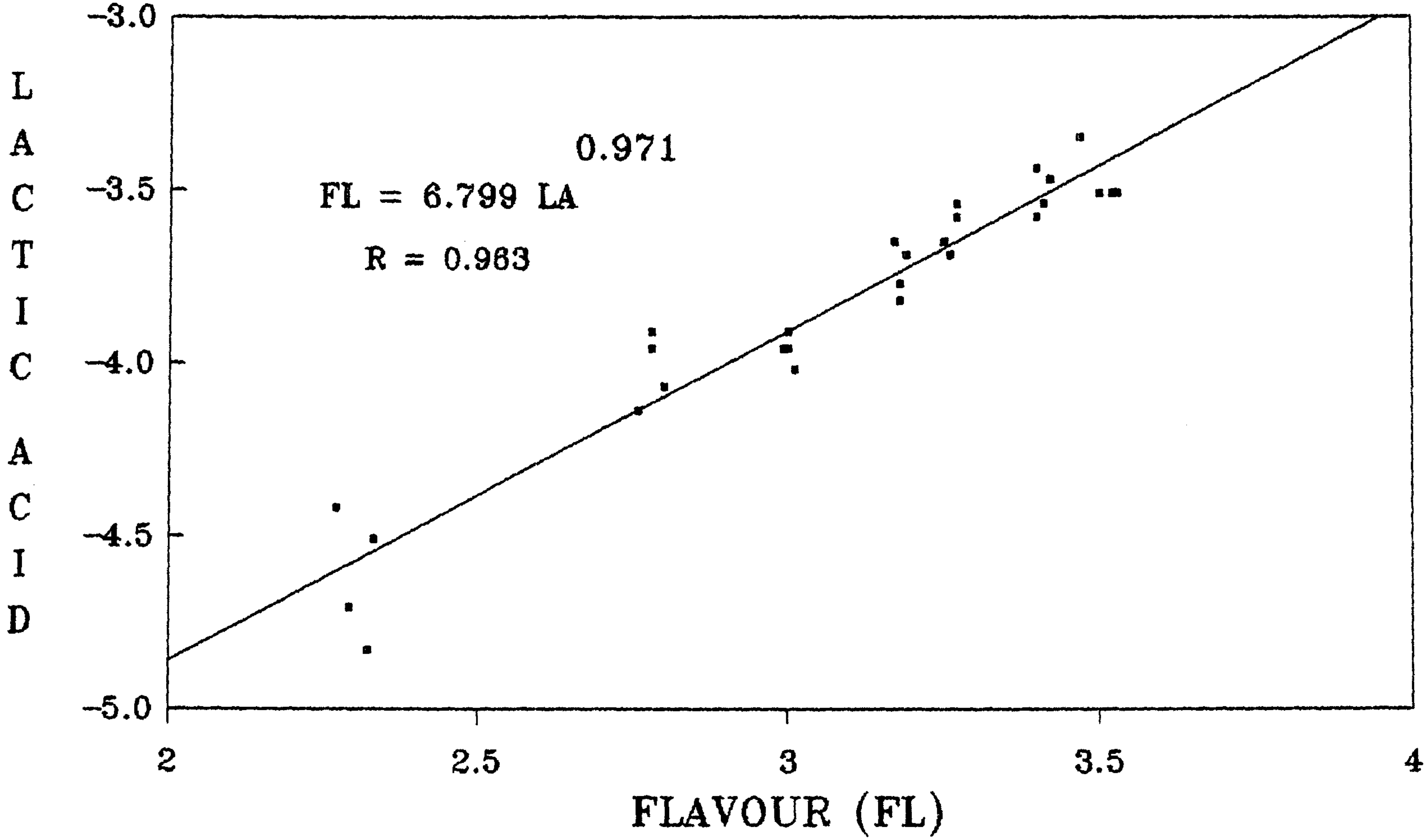


Fig. 29 . Relationship between flavour(FL) scores and lactic acid (LA%) of churpi at different days of drying

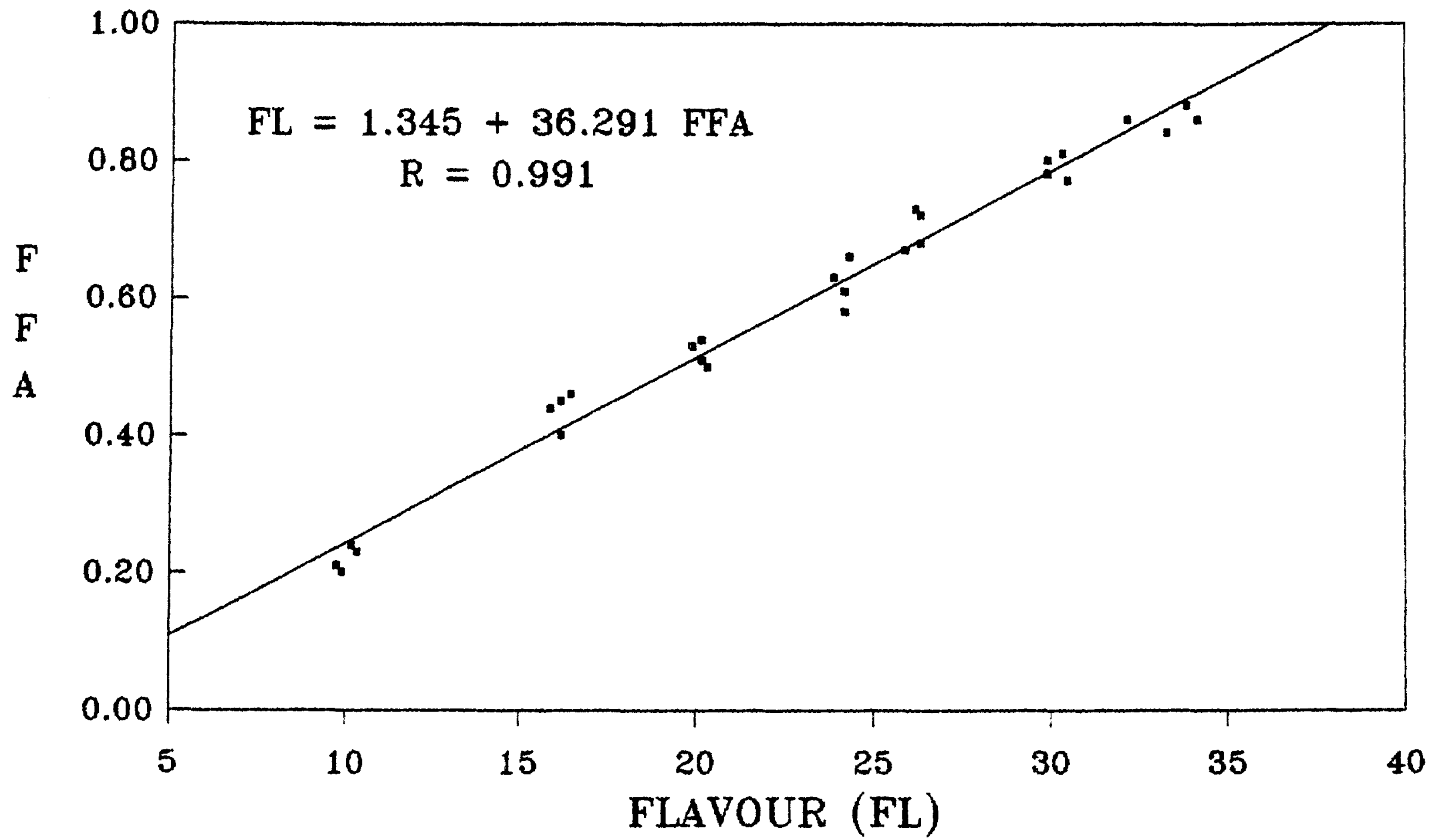
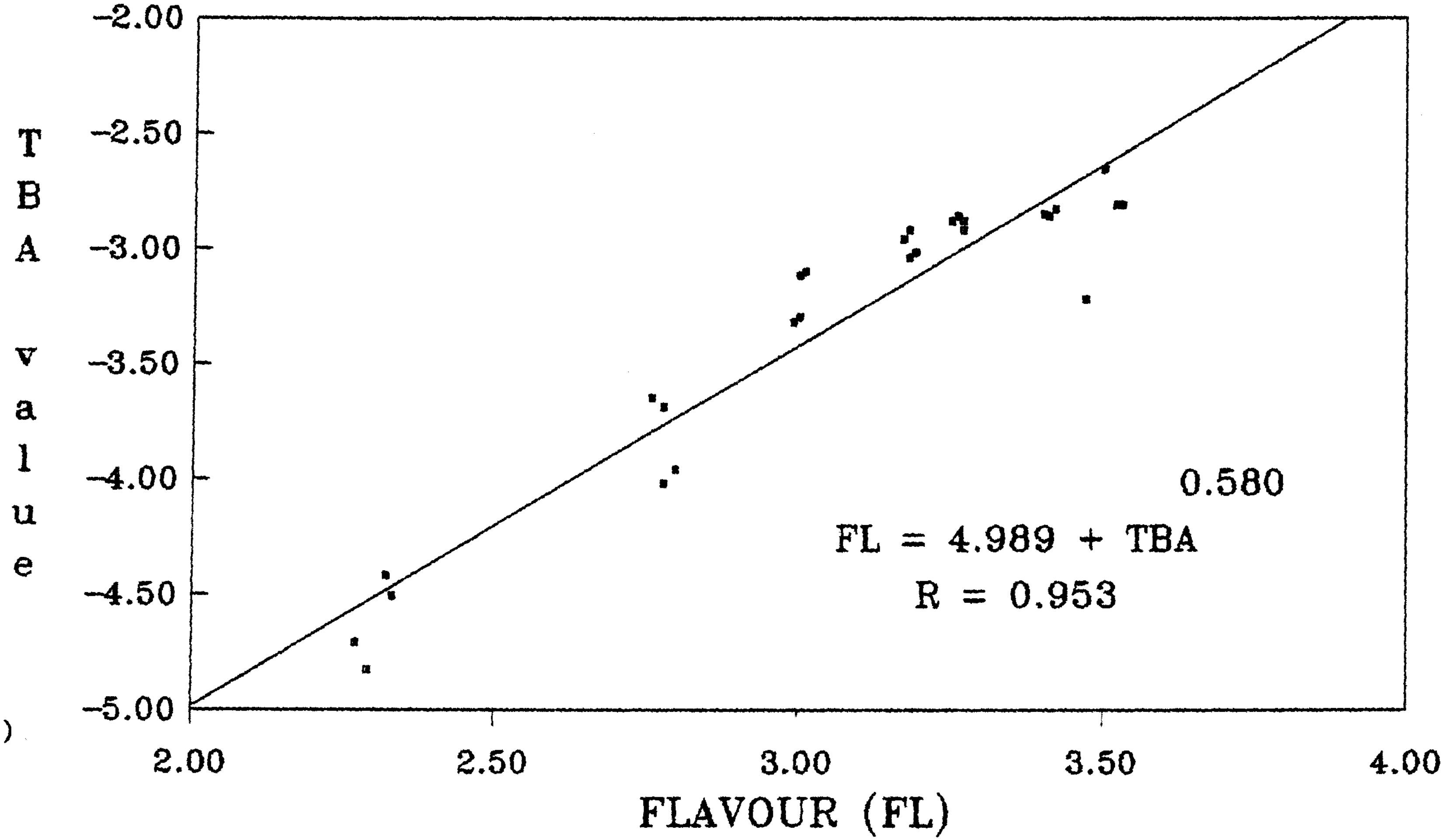
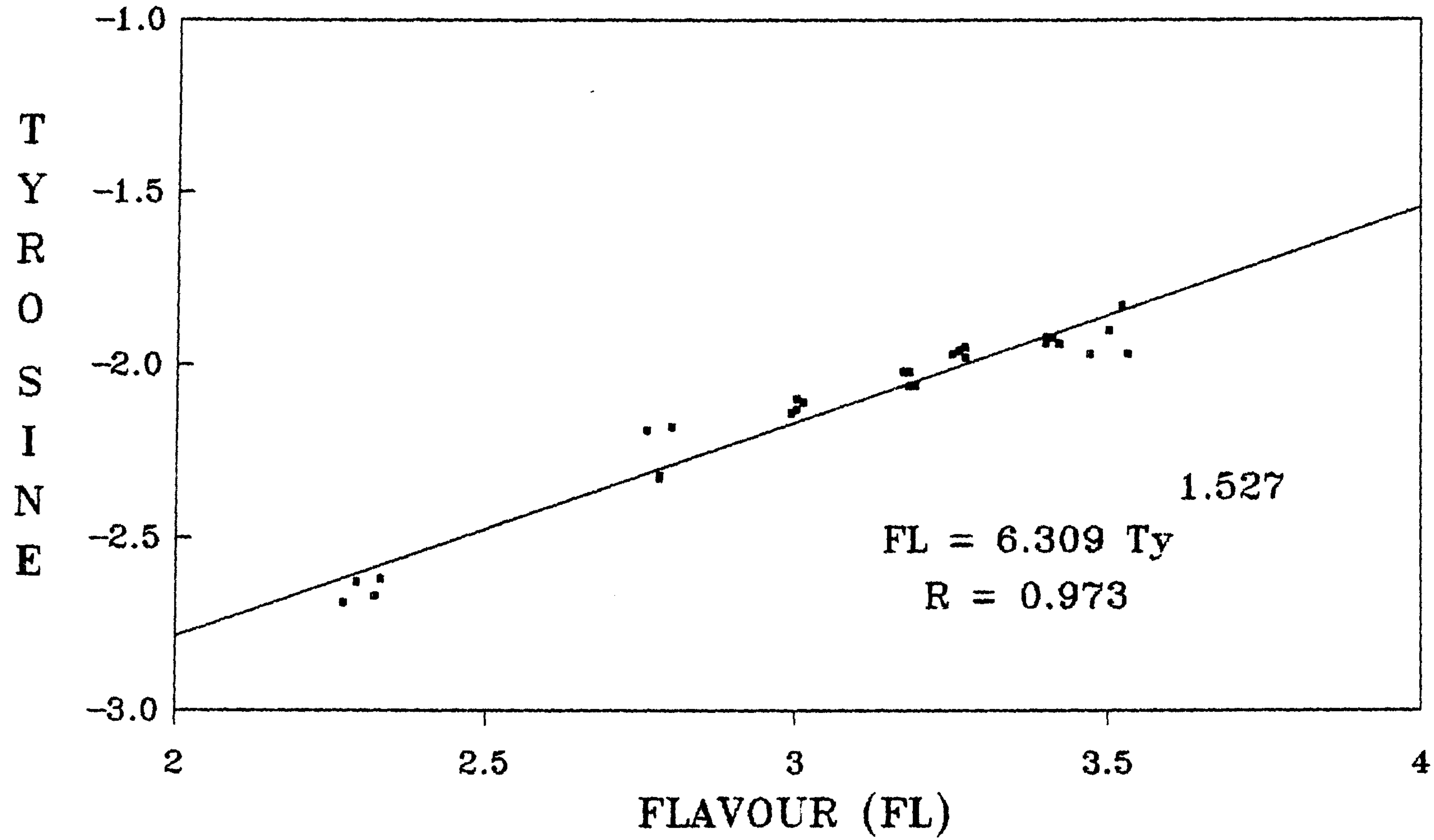


Fig. 30 . Relationship between flavour (FL) scores and free fatty acid (FFA%) of churpi at different days of drying



125)

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



g)

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

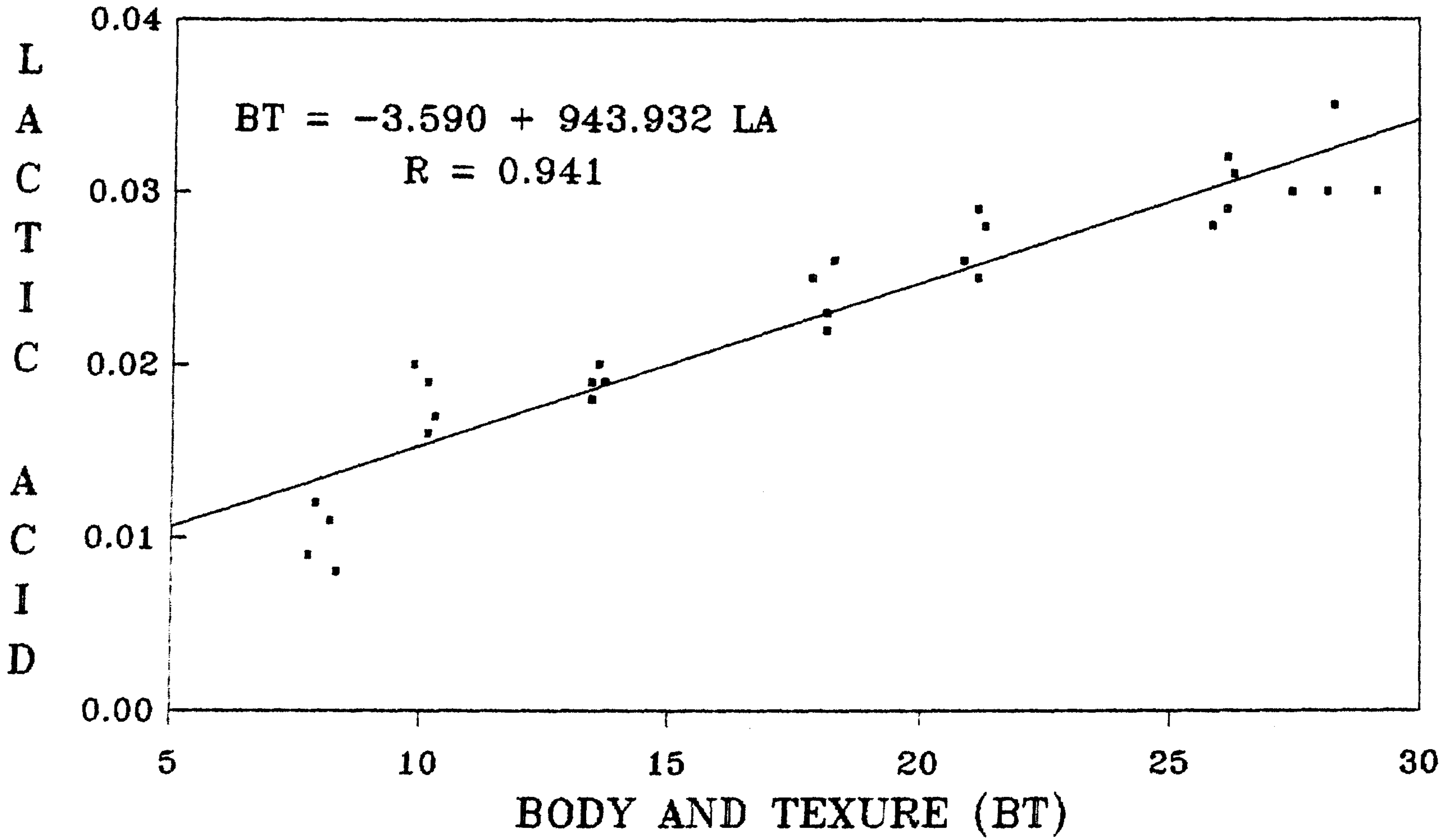


Fig. 33 .Relationship between body and texure(BT) scores and lactic acid(LA%) of churpi at different days of drying

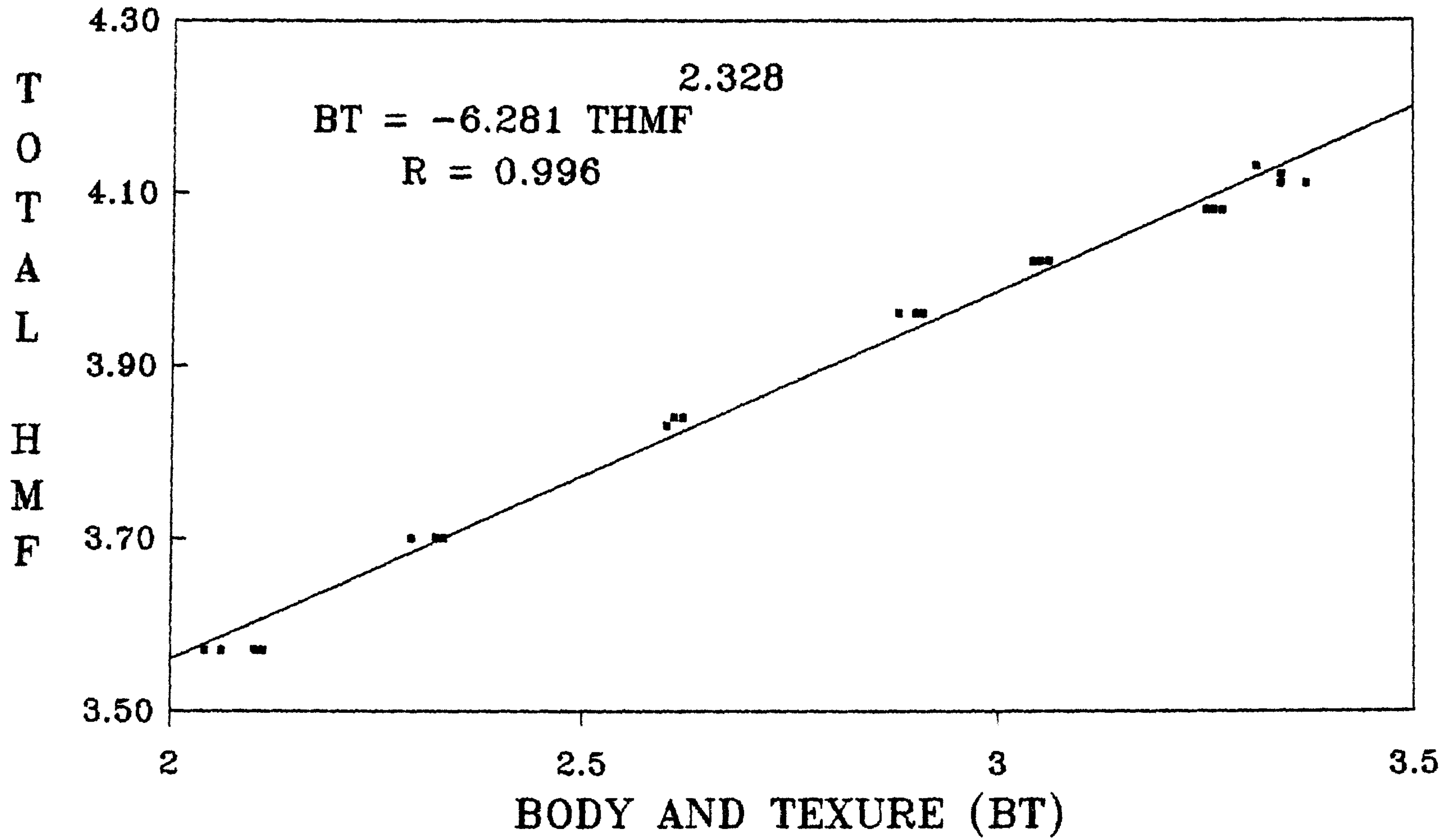


Fig. 34 . Relationship between body and texure(BT) scores and total HMF (micro moles/g) of churpi at diffrent days of drying

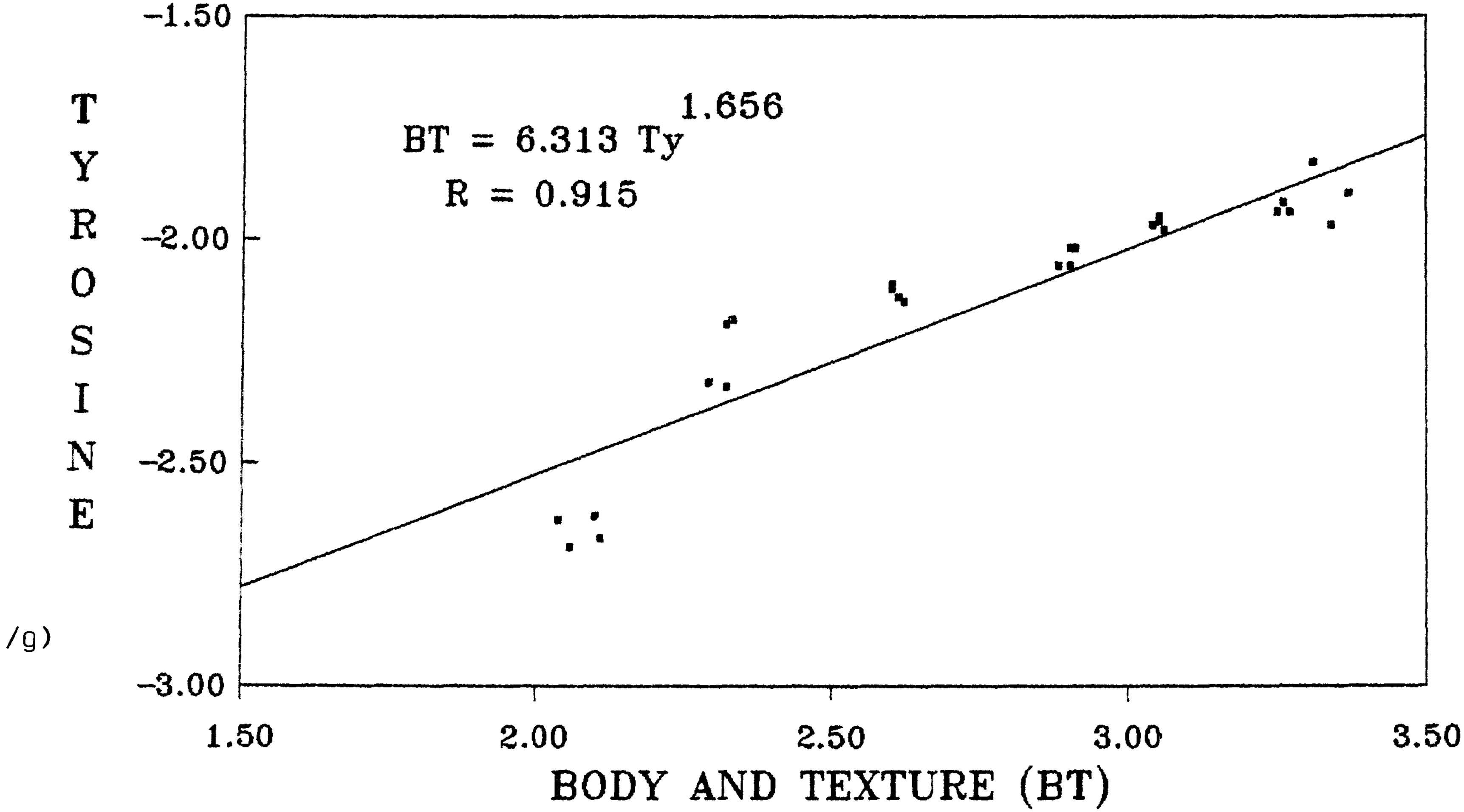


Fig. 35 . Relationship between body and texture (BT) scores and tyrosine(Ty) content of churpi at different days of drying

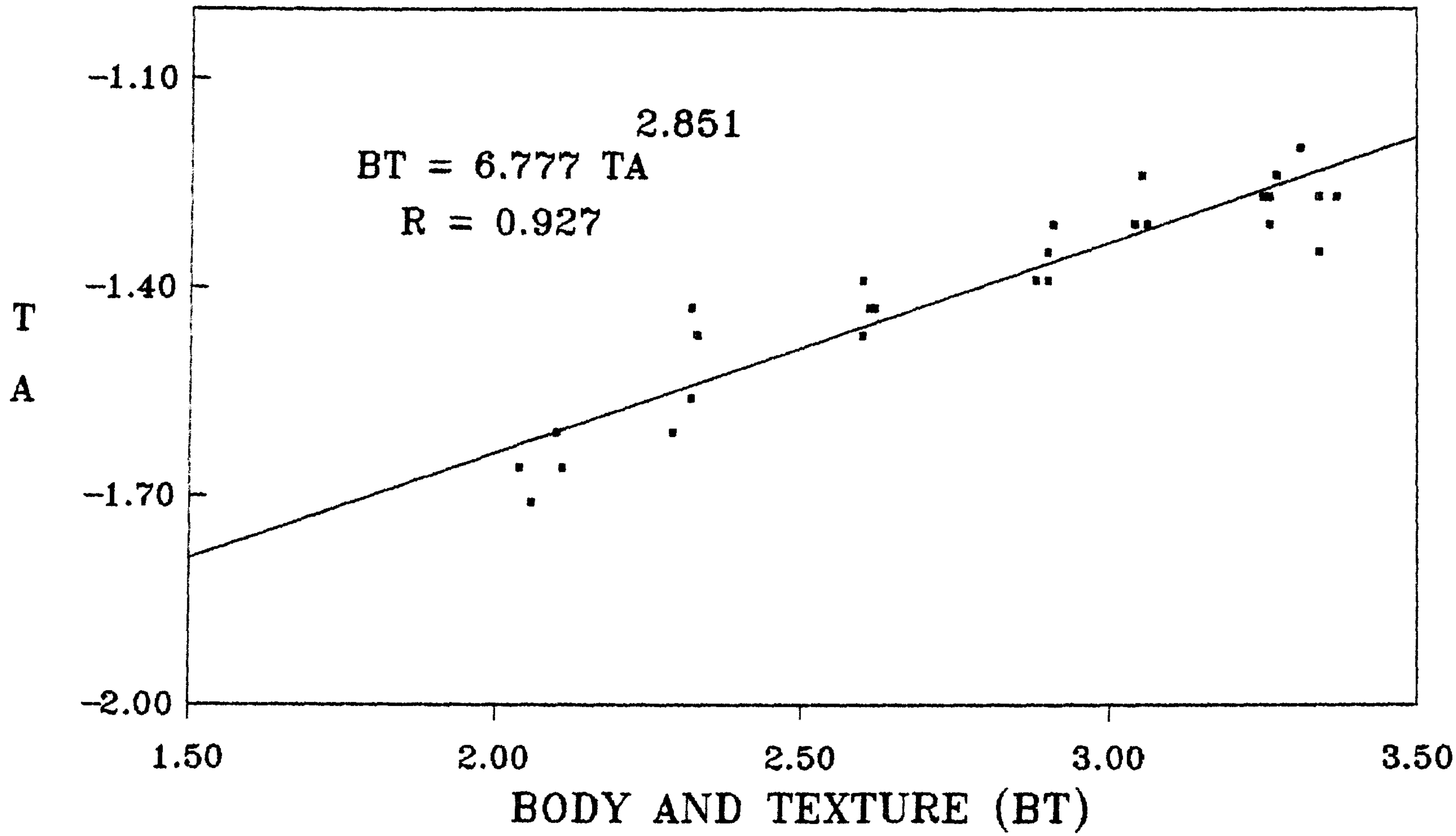


Fig. 36. Relationship between body and texture (BT)scores and tritatable acidity(TA%) of churpi at different days of drying

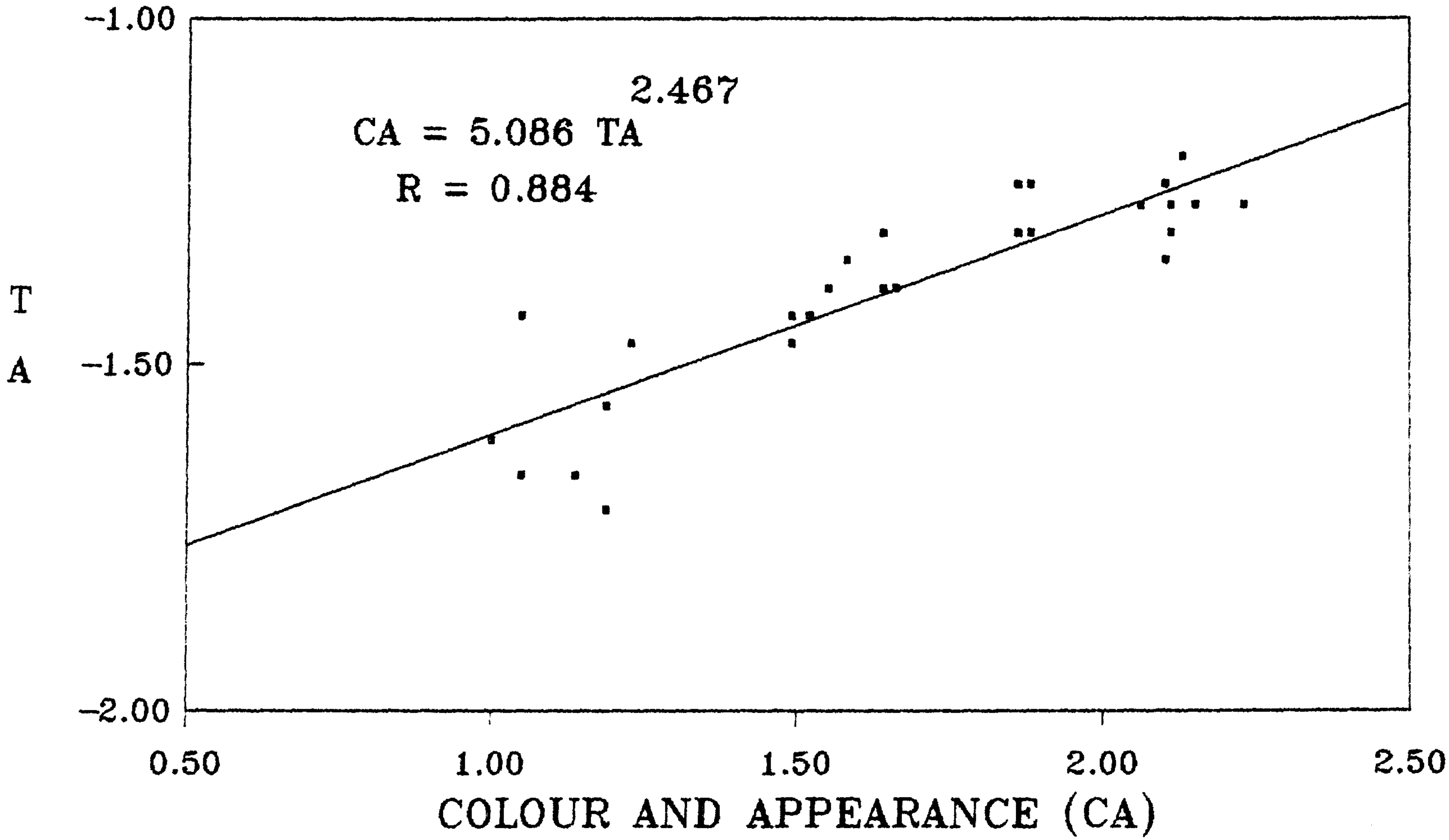


Fig. 37 . Relationship between colour and appearance (CA) scores and tritatable acidity(TA%) of churpi at different days of drying

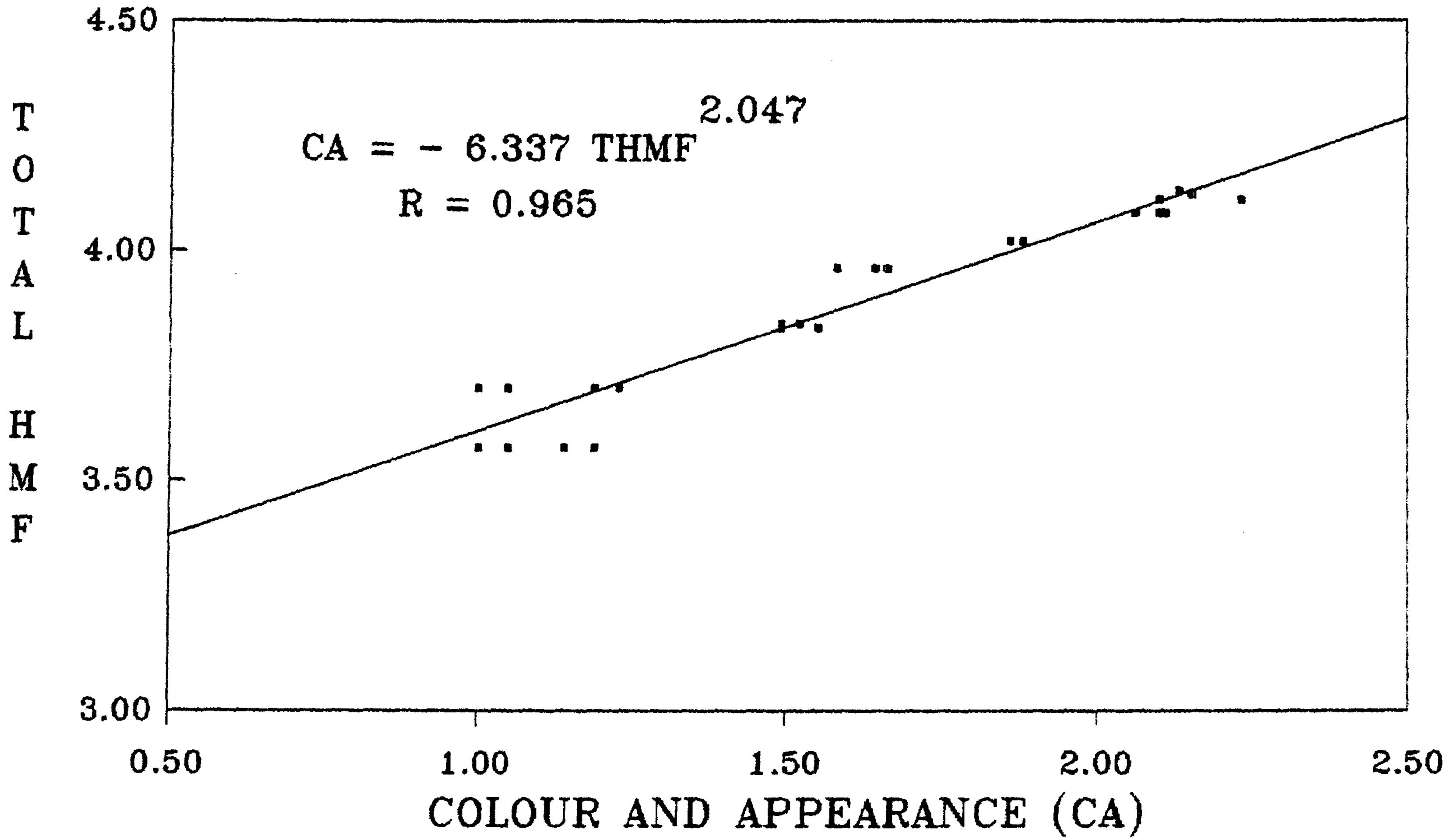


Fig. 38 .Relationship between colour and appearance (CA)scores and total HMF(micro moles/g) of churpi at different days of drying

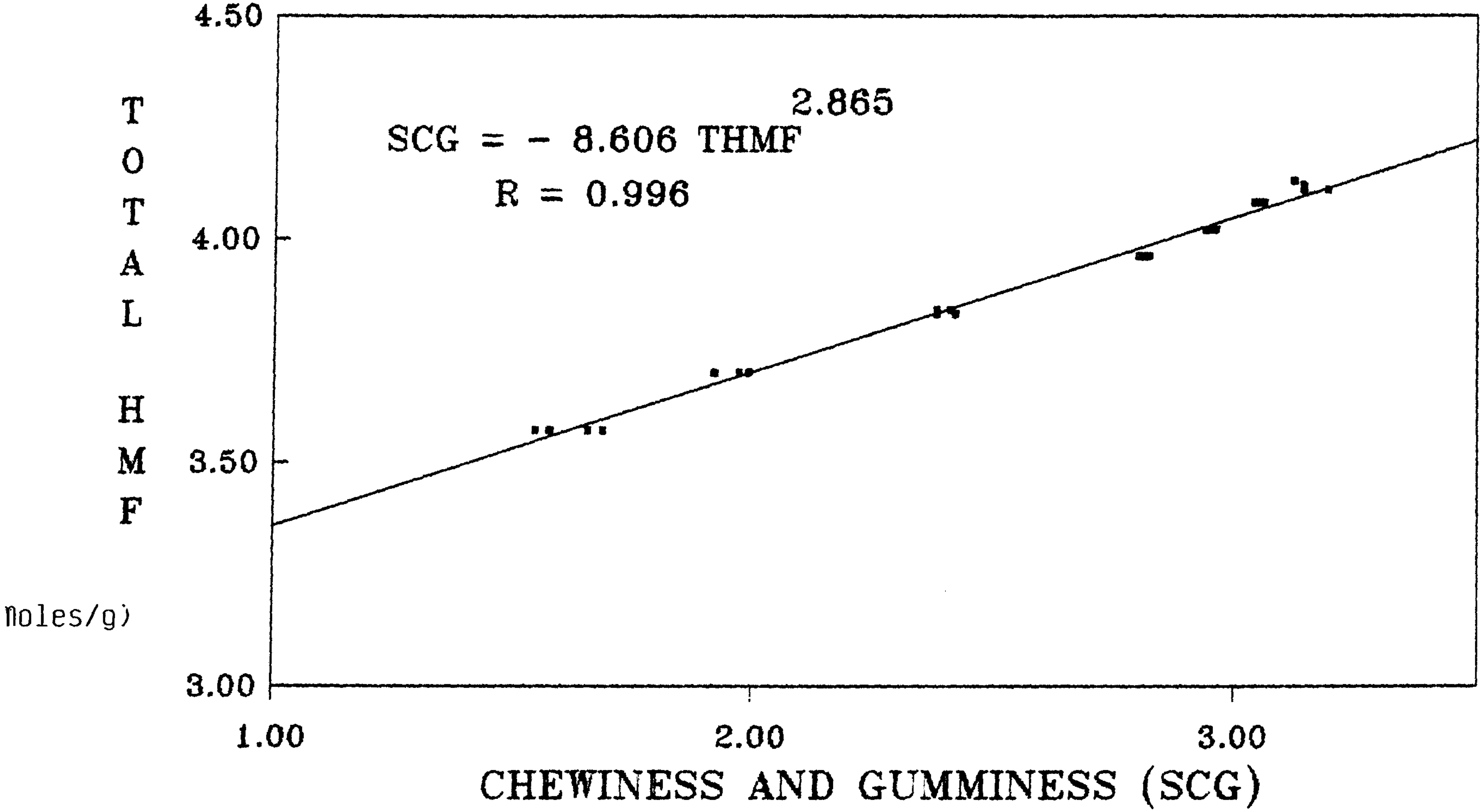


Fig. 39 . Relationship between chewiness and gumminess (SCG) scores and total HMF of churpi at different days of drying

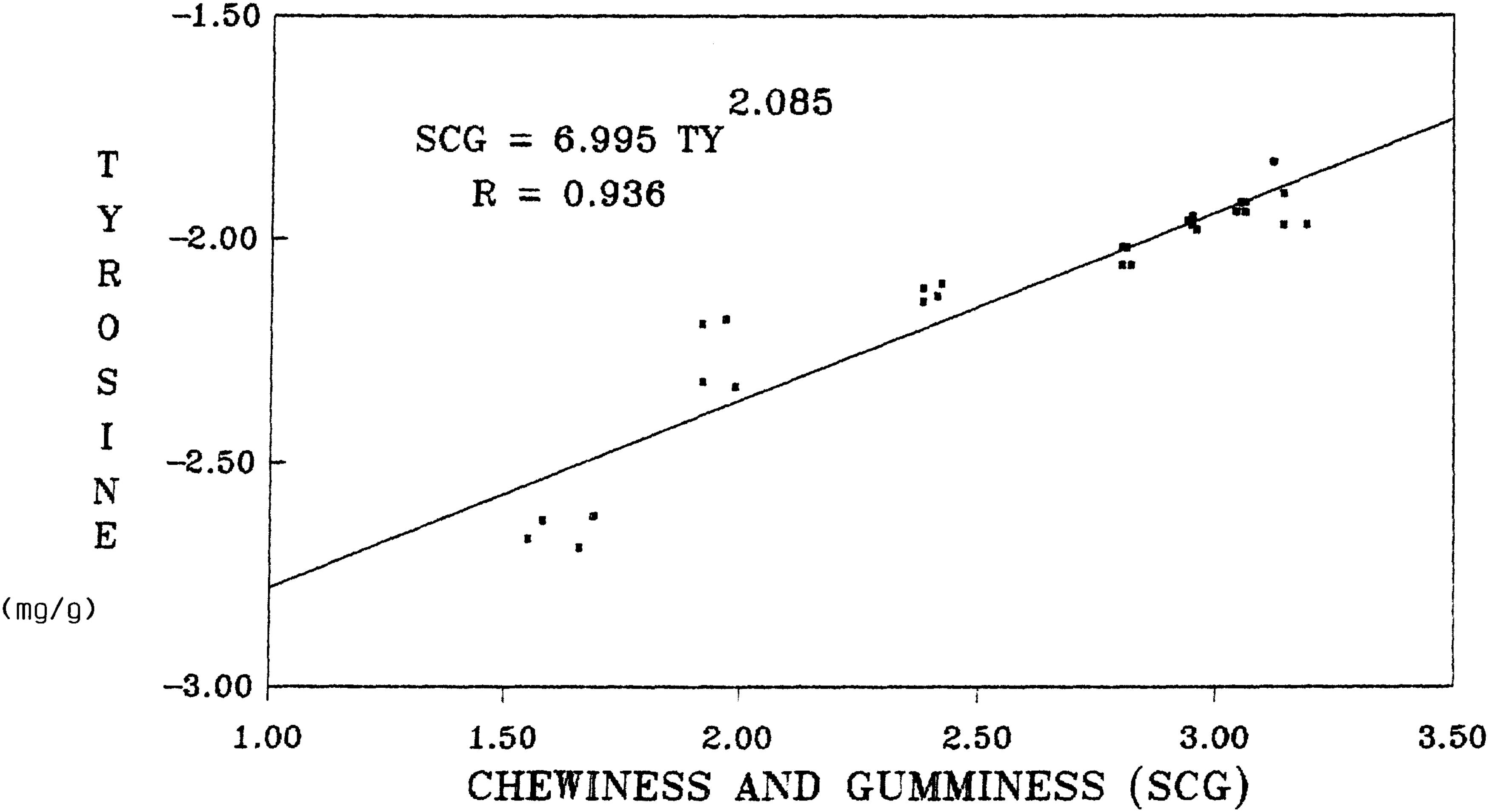


Fig. 40 . Relationship between chewiness and gumminess scores and tyrosine content of churpi at different days of drying

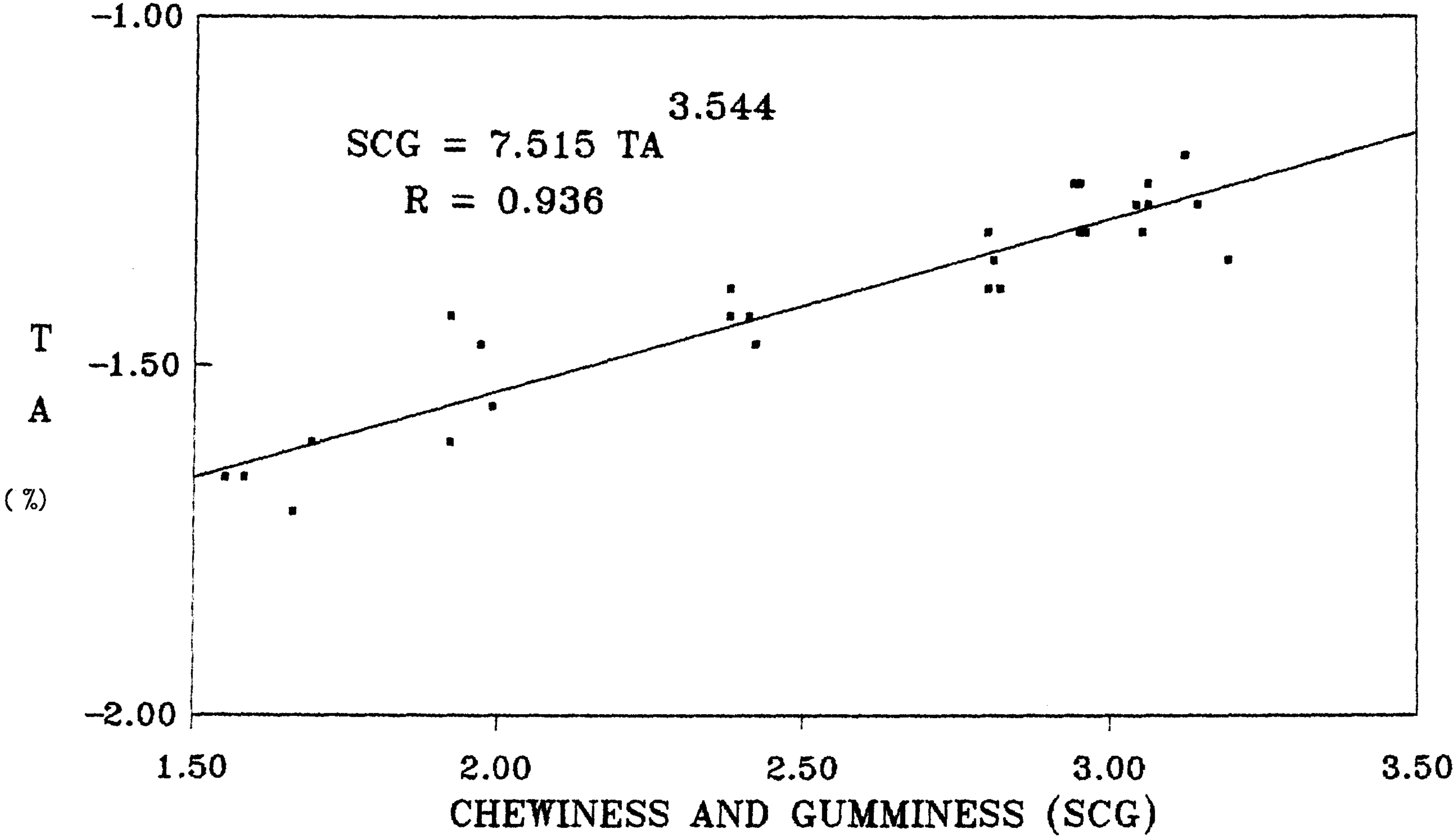


Fig. 41 . Relationship between chewiness and gumminess scores and tritatable acidity of churpi at diffrent days of drying

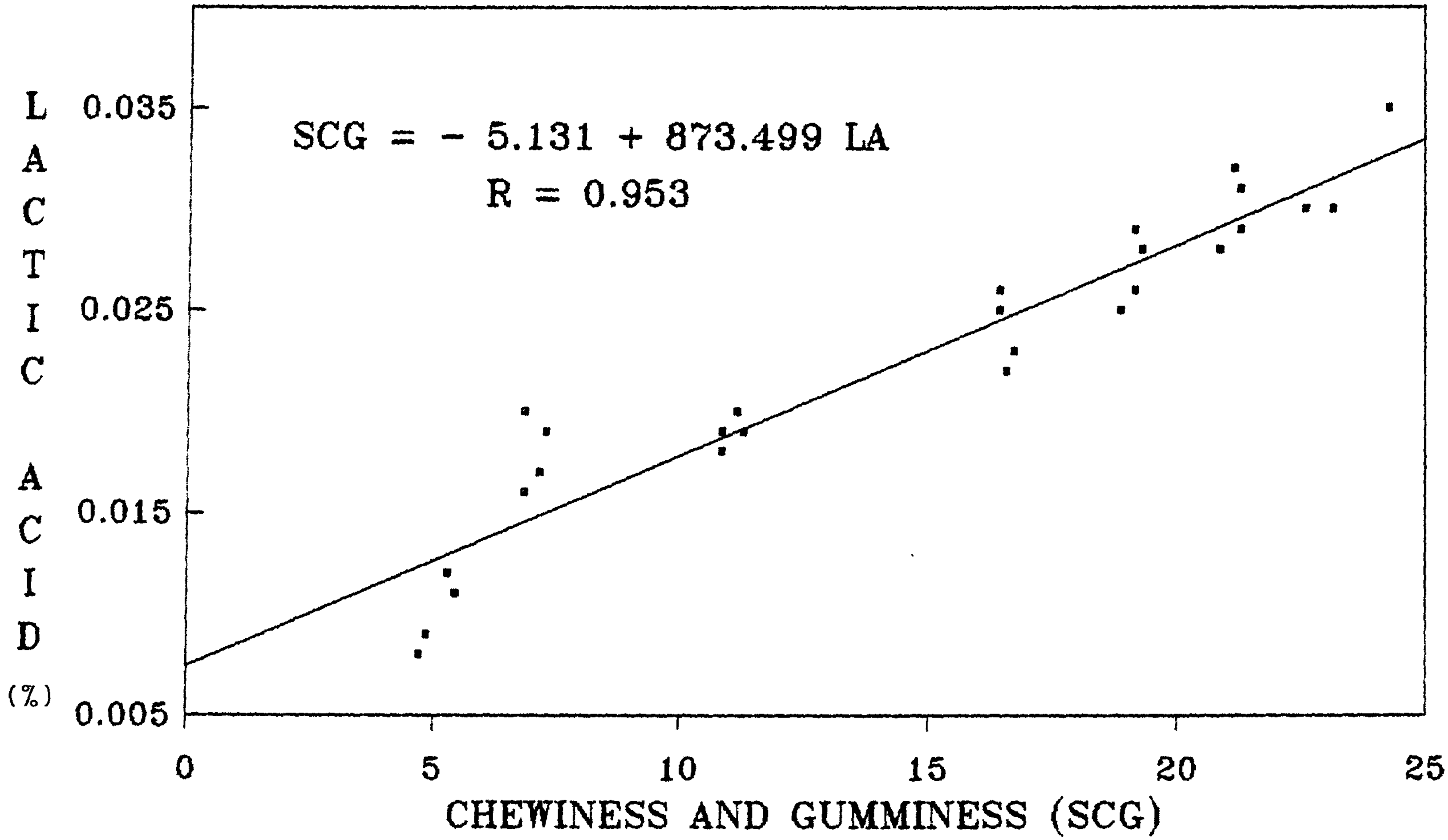


Fig. 42 . Relationship between chewiness and gumminess scores and lactic acid at different days of drying

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	$Fl = 6.799 LA^{0.971}$	0.96	0.93
2	$Fl = 4.989 TBA^{0.580}$	0.95	0.91
3	$Fl = 1.345 + 36.291 FFA$	0.99	0.98
4	$Fl = 6.572 TA^{2.510}$	0.94	0.89
5	$Fl = 18.513 + 0.825 THMF$	0.99	0.98
6	$Fl = 6.309 TY^{1.527}$	0.97	0.95
7	$Fl = 0.061 FFA^{0.507} . THMF^{0.880}$	0.99	0.99
8	$Fl = 19.190 - 12.663 TBA + 0.849 THMF$	0.99	0.99
9	$Fl = 3.985 LA^{0.283} . TBA^{0.020} . FFA^{0.760}$	0.99	0.99
10	$Fl = 6.484 LA^{0.506} . TBA^{0.159} . TA^{0.677}$	0.98	0.97
11	$Fl = 0.006 LA^{0.013} . FFA^{0.498} . THMF^{0.875}$	0.99	0.99
12	$Fl = -0.337 TA^{-0.097} . FFA^{0.522} . THMF^{0.918}$	0.99	0.99
13	$Fl = 4.634 LA^{0.165} . TBA^{0.034} . FFA^{0.584} . TA^{0.335}$	0.99	0.98
14	$Fl = -0.357 TA^{-0.099} . FFA^{0.524} . LA^{-0.003} . THMF^{0.920}$	0.99	0.99
15	$Fl = 0.216 TY^{0.105} . FFA^{0.433} . LA^{0.021} . THMF^{0.876}$	0.99	0.99
16	$Fl = -0.293 TA^{-0.127} . FFA^{0.496} . TBA^{0.024} LA^{0.004} . THMF^{0.916}$	0.99	0.99
17	$BT = 6.313 TY^{1.656}$	0.91	0.84
18	$BT = -6.281 THMF^{2.328}$	0.99	0.99
19	$CA = -6.337 THMF^{2.047}$	0.96	0.93
20	$CA = 5.086 TA^{2.466}$	0.88	0.78
21	$CA = 11.483 TY^{-0.751} . THMF^{2.957}$	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