Relationship of Sodium Carbonate SRC with Some Physicochemical, Rheological and Gelatinization Properties of Flour and its Impact on End Quality of Biscuit

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Abstract- Chemists are always in search of simple, rapid and inexpensive tests to replace time consuming, uneconomical and complex instrumental analysis. The present paper describes relationship of sodium carbonate Solvent retention capacity (SC-SRC) test association with some physicochemical and rheological properties of flour in view of their sorption capacities. The results have illustrated that SC-SRC values based on flour's multiple characteristics such as swelling power, water absorption, hydrophilicity and structural diversity of hydrophilic polymers affected rheological behavior that predicts end quality of biscuit. It was found that SCSRC was negatively correlated with flour moisture content and positively associated with water absorption capacity. Flour particle size (<125µm) also showed similar positive correlation. Farinograph's other parameters were also significantly predictive considering only SC-SRC value. Glutomatic proteins were not found linked with SC-SRC value. In conclusion it may be derived that SC-SRC test stands parallel to some cumulative results achieved from Farinograph, MVAG and Kernelyzer.

Index Terms- Biscuit quality, Soft wheat flour, Sodium carbonate SRC, Physicochemical parameters.

1. INTRODUCTION

It is well documented that every flour type is not equally suitable for producing a specific desired end product or to deliver the defined manufacturing process. Solvent retention capacity (SRC) tests have achieved a reliable status among simple chemical tests to be used for prediction of flour quality for assessing it's suitability for a specific product processing. Geng and co-workers (2012) have recently reported that the SRC method highlights some physicochemical properties of the Chinese soft wheat flours which are closely related to the rheological behaviour of the dough and predicts end quality of biscuits. The SRC method was introduced by Slade and Levine (1994) in the late 1980's, later it was implemented as an AACC approved method (Gaines, 2004). The suitability of SRC tests to assess the European wheat flour for cookie and bread has been established by Duyvejonck and colleagues (2012; 2011). Recently it is demonstrated that the swelling capacity of hydrophilic polymers such as damaged starch (DS) plays key role in predicting the baking performance of the flour. (Ali *et al.*, 2014). The water absorption apart from other conditions depends on pH of the solution. The 5% SCSRC solution gives pH 11 where OH groups are ionized and negatively charged. The solvent absorbed is related to content of DS and water absorbed by flour both the factors are inversely related to the diameter of cookies. The awareness about involving SRC tests to evaluate flour quality for producing biscuit is increasing worldwide. Chinese soft wheat flours were explored during the same time when European verities were under investigation for their chemical and rheological properties suitable for producing cookies (Geng *et al.*, 2012). SRC tests were found successful as quality predictors for comparatively evaluating physicochemical behaviour of Argentine wheat flours for cookie production (Colombo *et al.*, 2008).

SRC parameters are equally competent to assess processing activities in baking industries for example some mixing properties of wheat flour such as dough development time, water absorption and mixing tolerance index have been correlated with some SRC tests (Ram *et al*, 2005). SC-SRC test that approximately estimates damaged starch is related to a number of characteristics of wheat kernel, flour dough behaviour and end products. Tempering process is desired to modify milling properties of kernel and SC-SRC values were significantly reduced when moisture during the tempering is increased (Kweon *et al*, 2009). The components of flour obtained from SC-SRC may be used to control tempering respective to product type. Addition of water during tempering will improve flour quality for biscuit, cake and cracker making. SC-SRC values are negatively correlated to the width of the biscuits; less damaged starch is also required in flour for cracker making. An excellent review has been published recently (Kweon *et al*, 2011) where SRC value were found very informative in predicting flour functionality in the processing of wheat based products and also in selection of wheat breeding program. Recently Kweon and coworkers (2013) have related SRC values of the flour to the baking performance of dough and have broadly discussed the application of four SRC tests in identifying the flour suitability for biscuit processing.

In the present paper, we have investigated the usefulness of SRC tests in evaluating the baking performance of Pakistani soft flours for production of biscuits. The SCSRC test particularly

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was studied as a qualitative predictor of DS and its relationship to various parameters from Farinograph, Micro Visco-Amylograph, Glutomatic and Kernelyzer indicating that lengthy instrumental analysis may be replaced by simple SCSRC for immediate implementation during processing.

2. MATERIALS AND METHODS

2.1. Flour

Eighteen commercial soft and semi hard wheat flour samples were obtained from two different flour mills located at Karachi, Pakistan i.e. Masoom Flour Mills (Pvt.) Ltd (coded as M1 - M9) and Qandhari Flour Mills (Pvt.) Ltd (coded as Q1 - Q9) which are regular suppliers of flour for English Biscuits Manufacturers (Pvt.) Ltd.

2.2. Reagents

All reagents were obtained from Merck (KGaA 64271 Darmstadt, Germany). The 5% sodium carbonate SRC solution was made (w/w) according to International Method No. 56-11 (AACC, 2000).

2.3. Flour moisture

Flour moisture contents were determined with Brabender Moisture Analyzer (Brabander, Duisburg, Germany) according to International Method No. 44-19 (AACC, 2000). The 9 - 11g of flour samples were kept at 155°C for 20 min to get constant weight and weight loss is calculated as moisture percent.

2.4. Flour protein & ash

Flour protein and ash contents were determined using Brabender Kernelyzer (OmegAnalyzer, Bruins Instruments, Germany). The results are listed in table 1.

Table 1: Protein, ash and moisture contents of flour samples

Flour Samples	SC-SRC (%)	Protein (%)	Ash (%)	Moisture (%)
Q1	101	9.8	0.26	13.3
Q2	99	11.4	0.35	13.8
M1	83	9.9	0.22	14.6
Q3	79	9.8	0.36	14.7
M2	75	10.1	0.28	14.5
M3	89	9.9	0.24	14.3
M4	85	10.5	0.29	14.1
M5	86	10.4	0.31	14.5
Q4	102	10.1	0.25	13.4
M6	87	10.2	0.22	14.2
M7	87	10.2	0.23	14
Q5	95	10.1	0.29	13.8
M8	76	9.9	0.28	14.5
M9	87	9.8	0.28	14.5
Q6	101	9.9	0.28	13.7
Q7	86	10.9	0.43	13.8
Q8	99	9.9	0.24	13.8
Q9	98	9.9	0.24	13.8

2.5. Flour particle size

The particle sizes of different flours were measured as greater than 160 micron, between 160 to 125 and less than 125 micron by using Fritsch vibratory sieve shaker (Oberstein, Germany) set at 2 mm amplitude for 10 min. The results are reported in table 2.

Table 2: Particle size characterization of flour samples (greater than 160µm, between 160 to 125µm and less than 125µm)

Flour Samples	SCSRC (%)	>160µm (%)	160-125µm (%)	<125µm (%)
Q1	101	0.4	11.3	88.3
Q2	99	0.9	13.7	85.4
M1	83	0.6	13.7	85.7
Q3	79	1.3	13.7	85.0
M2	75	0.6	12.8	86.6
M3	89	0.5	12.2	87.3
M4	85	1.1	12.7	86.2
M5	86	1.3	13.0	85.7
Q4	102	0.5	10.7	88.8
M6	87	0.6	13.0	86.4
M7	87	0.8	13.4	85.8
Q5	95	0.5	12.7	86.8
M8	76	0.6	15.0	84.4
M9	87	0.6	14.5	84.9
Q6	101	0.4	10.2	89.4
Q7	86	0.7	13.7	85.6
Q8	99	0.6	12.8	86.6
Q9	98	0.5	12.5	87.0

2.6. Glutomatic parameters

The Perten Glutomatic (Huddinge, Sweden) was used to determine the amount and nature of various flour gluten proteins according to International Method No. 38-12 (AACC, 2000). The results are reported in table 4.

Table 4: Relationship of SCSRC to Glutomatic parameters

Flour Samples	SCSRC (%)	PG (%)	RG (%)	WG (%)	GI	WB (%)	DG (%)
Q1	101	6.2	19.9	26.1	76	17.6	8.5
Q2	99	3.6	23.3	26.9	87	18.0	8.9
M1	83	6.2	19.8	25.9	76	17.5	8.4
Q3	79	3.3	20.1	23.4	86	15.8	7.6
M2	75	2.5	21.8	24.3	90	16.1	8.2
M3	89	6.4	19.9	26.3	76	17.8	8.5
M4	85	2.6	23.0	25.6	90	17.4	8.2
M5	86	2.7	22.6	25.3	89	17.0	8.3
Q4	102	5.8	20.4	26.2	78	17.6	8.6
M6	87	3.2	23.1	26.3	88	17.6	8.7
M7	87	2.6	23.3	25.9	90	17.3	8.6
Q5	95	5.9	19.5	25.4	77	16.9	8.5
M8	76	9.4	17.8	27.2	65	18.5	8.7
M9	87	9.0	18.1	27.0	67	18.4	8.6
Q6	101	7.2	18.5	25.7	72	17.2	8.5
Q7	86	6.9	21.4	28.3	76	18.9	9.4
Q8	99	5.7	20.8	26.5	78	17.9	8.6
Q9	98	7.2	20.0	27.2	74	18.4	8.8

2.7. Farinograph parameters

The rheological properties of dough such as water absorption (WA), dough development time (DDT), farinograph dough stability (FDS), degree of softening (DoS) and farinograph quality number (FQN) were determined using Brabender Farinograph-E (Duisburg, Germany) according to International method no 54-21 (AACC, 2000) on 14% moisture basis and 500 ± 20FU (Brabender Unit) consistency that shows the dough strength of the flour. Water absorption (WA) in Farinograph is calculated from the amount of water required to produce a dough consistency of 500FU. The results are reported in table 3.

Table 3: Farinographic parameters of flour samples verses sodium carbonate SRC

Flour Samples	SCSRC (%)	WA (%)	DDT (min)	FDS (min)	FQN	DoS (BU)
Q1	101	62.4	1.9	6.5	85	62
Q2	99	61.6	5.5	6.0	83	80
M1	83	55.9	6.7	9.6	122	52
Q3	79	55.6	2.0	9.1	102	53
M2	75	57.5	7.7	10.3	143	47
M3	89	58.6	1.9	9.1	115	42
M4	85	59.4	6.8	8.6	112	60
M5	86	58.9	6.2	8.1	101	62
Q4	102	62.0	4.3	6.6	88	66
M6	87	58.7	6.0	5.9	103	59
M7	87	58.3	6.8	4.9	125	49
Q5	95	60.8	5.5	6.9	93	68
M8	76	57.4	6.2	7.8	101	61
M9	87	57.8	5.4	7.2	89	69
Q6	101	62.9	1.9	4.8	60	74
Q7	86	60.7	4.7	6.1	81	72
Q8	99	61.8	1.9	5.9	78	67
Q9	98	61.6	5.5	7.1	100	64

2.8. Micro Visco-Amylograph parameters

The gelatinization and pasting properties of flour samples were measured using Micro Visco-Amylograph (Brabender, Duisburg, Germany) according to International Method No. 22-12 (AACC, 2000). A sample of 15g (on basis of 14% moisture) was transferred to the cup and 100 ml of distilled water was added. The slurry formed was heated to 50°C and stirred at 160 rpm for 10 s for thorough distribution of ingredients. The mixture was then held at 50°C for 1 min and then heated to 95°C over a period of 7.3 min. The slurry was held at that temperature for 5 min (holding time for evaluating the pasting strength) and finally the mixture was cooled to 50°C over a period of 7.7 min. The various viscosities were measured from the pasting curve and the results are given in table 5.

2.9. Sodium carbonate SRC profile

Sodium carbonate SRC profile obtained is based on the International Method No. 56 - 11 (AACC 2000) with some modifications. Flour samples (1g) were suspended in 5% sodium carbonate to hydrate for 20 min (vortexed for 5 second each at 5, 10, 15, and 20 minutes) and then centrifuged at 1,000 × g for 15 minutes. The supernatant was decanted and the tube was drained at a 90° angle for 10 min on a paper towel. Each precipitate obtained was weighed and the SCSRC value for each sample was calculated according to Haynes *et al*. (2009) as described in International Method No. 56 - 11 (AACC, 2000).
All sodium carbonate SRC (SCSRC) analyses were at least performed in triplicate and the coefficient of variation of the SRC values was less than 2.0%. The results are reported in all tables from 1-5 for comparison.

2.10. Preparation of biscuits

The biscuits were prepared in lab according to International Method No. 10-31B (AACC, 2000) with some modifications. Flour (228g, corrected to 14% moisture), sodium bicarbonate (3.4g), mono calcium phosphate (4.1g) and salt (4.5g) were all mixed together in Kenwood chef Mixer (Model Series: KM001, Kenwood Ltd, Britain). Then shortening (40g) was added to flour and mixed at speed of 1 for 3 min. then 135g of milk solution (50g milk powder in 450g of distilled water) was added and mixed again at speed 1 for 15s. The dough was sheet in lab with manual sheeting unit of 1 mm thickness and the biscuits were cut on ungreased baking sheet through round cutter having inner diameter as 49mm. the biscuits were baked for 10 min in Nardi lab oven (Italy) at 230°C.

2.11. Evaluation of biscuit quality

The biscuit dimensions were measured, including parameters such as the weight of 8 biscuits, total diameter and total thickness of eight biscuits were recorded as defined in International Method No. 10-31B (AACC, 2000). The biscuits were picked up at random and the diameter was measured by turning each biscuit three times at different angles and the mean of eight biscuits were reported. While the thickness as estimated by stacking method taking the mean of the height of eight biscuits. The spread factor or the cookies factor is the ratio between the width (W) and height (H) was calculated according to the method of Colombo *et al* (2008). It is used as an indicator of the baking quality of biscuit. The results are reported in table 6.

2.12. Statistical Analysis:

The data collected were analysed according to standard statistical procedures using Microsoft Excel (2007). Linear correlation coefficients among different quality factors were determined through Microsoft Excel (2007) by making scattered graph between data of two different parameters and finding their R square value (R^2) through trend line.

Table 5: Relationship of SCSRC to Micro Visco-Amylograph parameters of flour samples

Flour Samples	SCSRC (%)	Beginning of Gelatinization (°C)	Maximum Viscosity (MV)	Trough Viscosity (TV)	Final Viscosity (FV)	Breakdown Viscosity (BV = MV - TV)	Setback Viscosity (SV = FV - TV)
Q1	101	60.1	1083	653	1219	430	566
Q2	99	60.4	1016	595	1104	421	509
M1	83	60.0	1076	730	1303	346	573
Q3	79	60.5	1097	686	1300	411	614
M2	75	60.8	1113	716	1289	397	573
M3	89	61.1	1064	692	1266	372	574
M4	85	60.8	1050	695	1328	355	633
M5	86	60.3	1099	700	1270	399	570
Q4	102	59.9	1046	637	1167	409	530
M6	87	59.9	1067	691	1264	376	573
M7	87	60.1	1112	718	1298	394	580
Q5	95	59.0	1061	666	1257	395	591
M8	76	60.5	1081	679	1225	402	546
M9	87	60.0	1060	679	1258	381	579
Q6	101	59.2	1050	654	1219	396	565
Q7	86	60.4	1058	602	1110	456	508
Q8	99	59.8	1024	668	1255	356	587
Q9	98	60.4	1049	659	1222	390	563

Table 6: Relationship of sodium carbonate SRC and biscuit end quality parameters

Flour Samples	SCSRC (%)	Dry Weight (g)	Total Diameter (W) (mm)	Total Thickness (H) (mm)	Spread Factor (W/H)
Q1	101	75	363	60	6.1
Q2	99	61	358	69	5.2
M1	83	62	354	76	4.7
Q3	79	60	357	76	4.7
M2	75	58	346	76	4.6
M3	89	64	368	71	5.2
M4	85	57	374	67	5.6
M5	86	67	359	74	4.9
Q4	102	65	366	71	5.2
M6	87	73	350	79	4.4
M7	87	71	351	82	4.3
Q5	95	65	347	73	4.8
M8	76	72	367	82	4.5
M9	87	80	361	86	4.2
Q6	101	79	366	78	4.7
Q7	86	79	365	81	4.5
Q8	99	74	371	73	5.1
Q9	98	72	366	72	5.1

3. RESULTS & DISCUSSIONS

3.1. Physicochemical properties

The flour samples were analysed for their moisture, protein and ash contents as shown in Table 1. A narrow variation range of ash and moisture was observed from 0.22 to 0.36% and 13.3 to 14.7% in the two parameters respectively. A strong but negative correlation was observed between SCSRC values and the moisture content of the flour as indicated in Figure 1, which is well expected. It does not represent the water absorbed by flour which is determined as the water absorption from Farinograph. Higher SC-SRC values in fig-1 indicated higher amount of damaged starch (DS) that will be produced if moisture in grain decreases, making the kernel harder. Hard wheat always produce more DS because more force and pressure are required for grinding and that damages the starch granule (Kweon *et al*, 2009). Millers therefore use tempering in case of hard wheat processing to make grain softer and to produce soft flour consisting less DS as particularly desired for production of biscuit, cakes and crackers etc.

SC-SRC indicating the amount of DS present in the flour has been found to be positively correlated with the fine particle size of the flour. The Table 2 compares the SC-SRC values with flour particle sizes of greater than 160 micron (>160µm), between 160 to 125 micron (160µm - 125µm) and less than 125 micron (<125µm) of the various flour. The variation is least in the larger particle size (0.9) as compared to finest particles (<125µm) where it varies between 84.4 to 89.4%. The Figure 2 shows positive correlation between finest particle size and the DS produced, i.e. it shows more DS will be produced on further reduction of the particle size. The milling process also suggests that as the quality of moisture contents will increase the grain will become harder and will produce more DS.

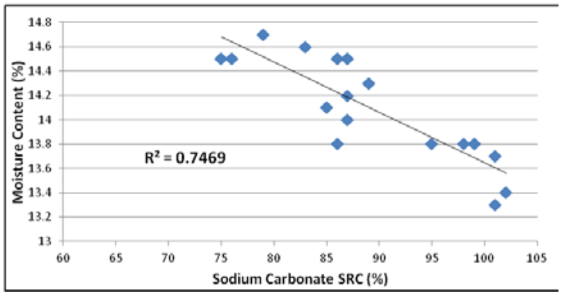


Figure 1: Relationship between moisture content and sodium carbonate SRC values of flour samples

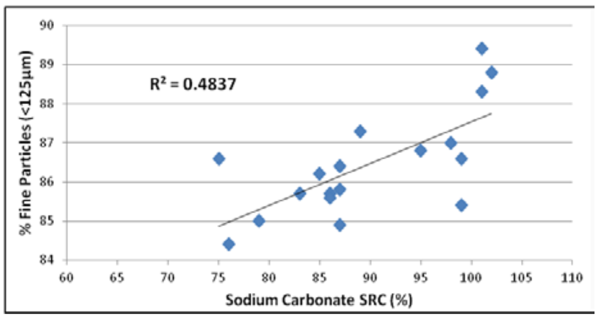


Figure 2: Relationship between sodium carbonate SRC to percent finer particles (below 125 µm) of flour samples

3.2. **Farinograph parameters**

In order to study the rheological behaviour of flour samples, the Farinographic parameters of all flour samples were determined. Water absorption (WA) ranged from 55.6 - 62.9%, dough development time (DDT) 1.9 - 7.7 min, Farinograph dough stability (FDS) were 4.8 - 10.3 min, degree of softening (DoS) were recorded from 42 to 80 BU (as defined by ICC, 12 min after peak time) and Farinograph quality number (FQN) varied between 60 - 143 (Table 3).

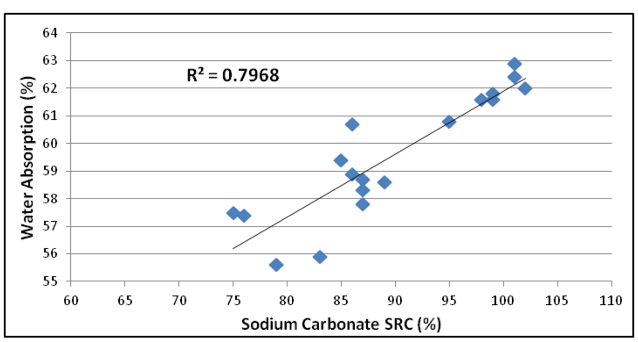
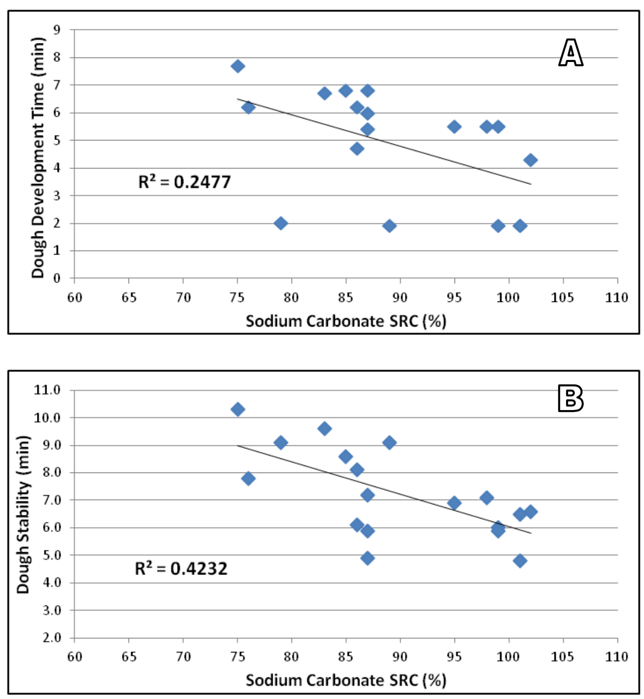


Figure 3: Relationship between sodium carbonate SRC to Farinograph water absorption of flour samples

It was found through graphical representations that SC-SRC and WA are closely interlinked to each other and the flour with more SCSRC values will have higher WA (Figure 3) as reported earlier in literature by several scientists (Barrera *et al*, 2007, Sudha *et al*, 2007, Ward *et al*, 2002). The WA determined through Farinograph is a sum of water needed by all hydrophilic components of flour while sodium carbonate SRC mainly represents the solution needed due to damaged starch (DS) content of flour. The reason for wide variation in the amount of DS in flour samples may be attributed to initial moisture present in the kernel, amount of tempering water, temperature of the tempering water and process of reduction during milling. DS content or the SCSRC values also vary because of the total quantity and type of proteins present in the flour. The flour will low WA is preferred for biscuit processing as it spreads more during baking producing large diameter. The DDT, FDS and FQN are inversely related to SCSRC values as shown in Figure 4-A, B & C respectively, these values may be attributed to rise in WA with increase in SCSRC values shown in Figure 3. Dough will naturally take longer time to develop in presence of less water (less DS) as shown by lower SCSRC values. Higher DDT may be explained on the basis of more mixing time required to distribute the water absorbed uniformly. Farinograph dough stability will also decrease with increase in DS because more water will be taken by DS to produce sticky dough, while less water will be available for glutenins to make strong network and dough will get sticky. Similar behaviour of dough is shown while comparing the FQN values with SCSRC (Figure 4-C). FQN shows the strength of flour and differentiate between hard to soft flour, so FQN will decrease with rise in DS. However the DoS is positively correlated with DS (Figure 4-D) as dough gets soft with increase in the amount of DS.



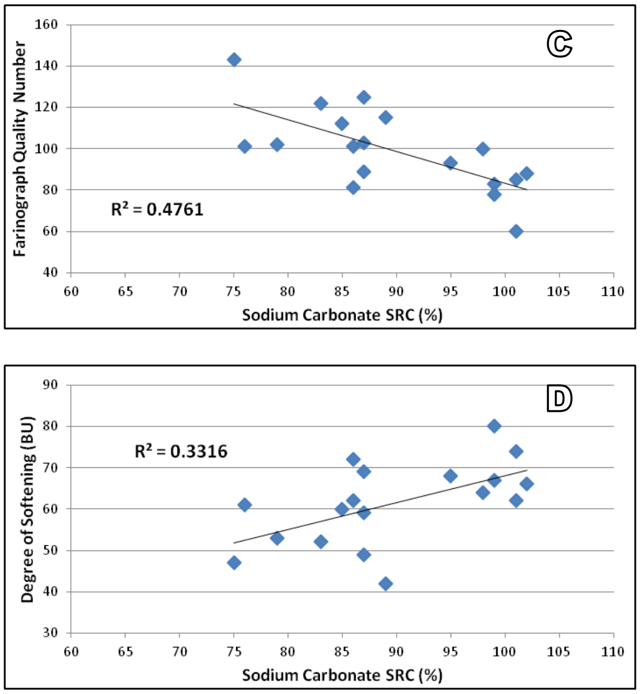


Figure 4: Relationships of sodium carbonate SRC to dough development time (A), Farinograph dough stability (B), Farinograph quality number (C) and degree of softening (D).

3.3. Glutomatic parameters

The Glutomatic parameters were also evaluated to find the relations of SCSRC to passed gluten (PG), retained gluten (RG), wet gluten (WG), dry gluten (DG), water binding (WB) and gluten index (GI) (Table 4). The gluten indexes of flour samples were ranged from 65 to 90 and dry gluten was 7.6 to 9.4 percent of flour weight. The relationships of various proteins as determined by Glutomatic, although, were not expected to be associated with SCSRC because damaged starch is not measured through Glutomatic. However the test was performed to evaluate the covalent linkages between starch and gluten proteins which on damage to starch molecules during milling may effect the passage of starch bound proteins through the sieves.

3.4. Micro Visco-Amylograph parameters

The Micro Visco-Amylograph parameters were also investigated to understand the relationship of SCSRC to various viscosities, gelatinization and pasting properties of flour inherent starches (Table 5). Beginning of gelatinization temperature was found less with higher values of SCSRC (Figure 5). It indicates that the higher content of damaged starches i.e. higher SCSRC values cause the starch to gelatinization at lower temperatures.

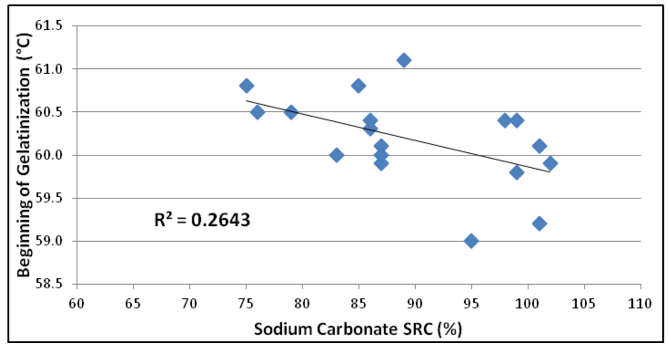


Figure 5: Relationship of sodium carbonate SRC to Beginning of gelatinization temperature of flour samples determined through Micro Visco-Amylograph.

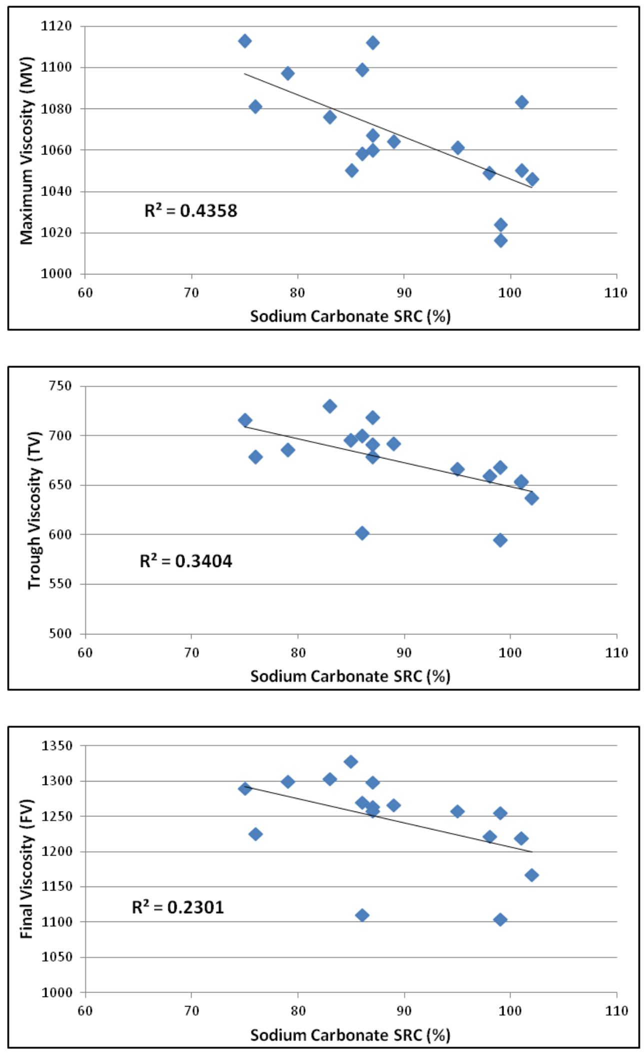


Figure 6: Relationships of SCSRC to maximum viscosity (A), trough viscosity (B) and final viscosity (C) of the flour samples

The relationship of rising damaged starch or high SCSRC values found with maximum viscosity (MV), trough viscosity (TV) and final viscosity (FV) were all found to be negatively correlated. MV shows holding strength at highest temperature (95°C) which decreases with rise in the amount of DS (Figure 6-A, B & C). No relation was found with breakdown (BV) and setback (SV) viscosities indicating less interaction of DS with water molecules, also water holding capacity of DS is decreased.

3.5. Baking evaluation of performance

The biscuits were baked as per method defined earlier, the group of eight biscuits of all flour samples had total diameter between 346 - 374mm, total thickness between 60 to 86mm and total weight varied from 56.8 to 80.1g (Table 6). No relation of sodium carbonate SRC values were found to biscuit quality parameters, but slight relation was observed with total thickness of biscuits (Figure 7). The relation revealed that the higher sodium carbonate SRC values leads to decrease in thickness of biscuits.

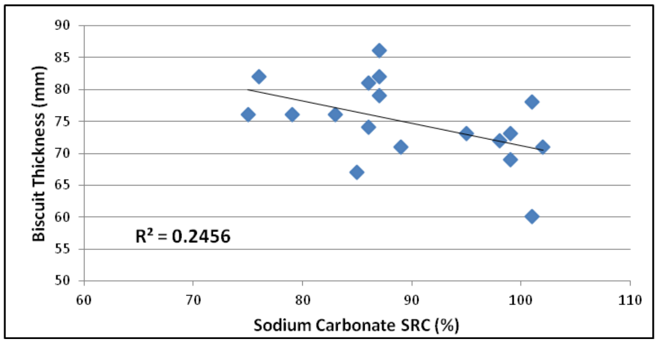


Figure 7: Relationship of sodium carbonate SRC to thickness of the biscuits made from flour samples

The spread factor or cookie factor was found to be related to sodium carbonate SRC values (Figure 8). The cookies factor represents the ratio between width and the height of eight cookies picked at random is related to SCSRC values that increase with DS as reported earlier (Zhang *et al*, 2007).

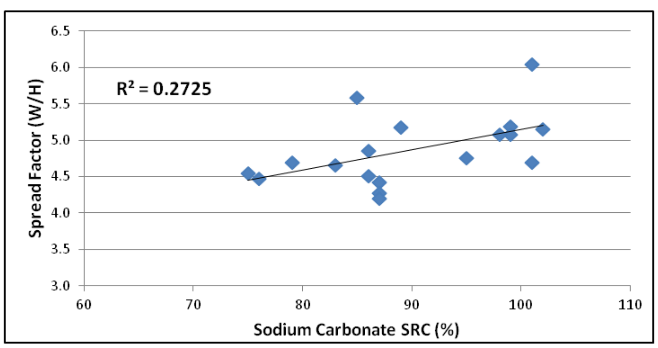


Figure 8: Relationship of sodium carbonate SRC to spread factor (ratio between width and height) of the biscuits

4. **Implication to Research and Practice:**

The implication of present research will generate a meaningful coordination between millers and processors to consider SRC analysis as criteria for flour quality. SRC test being very economical will be implemented at the milling units where expensive instruments are not acceptable especially in under developed countries.

5. **Conclusion:**

The studies have revealed that SCSRC test may be used in place of Farinograph to give water absorption; Moreover, SC-SRC is found to be a useful predictor of the quality of flour to identify the dimensional properties of biscuit. For example, the range of SRC values of the flour will forecast the diameter and thickness of the biscuit in a particular recipe. The hydrophilicity of DS as determined by SRC may be compared with the WA by other molecules. Water acts as the plasticizer in dough development, so water uptake by other components will affect dough rheology and end quality. It seems that SCSRC test alone may play key role in evaluation and controlling the quality of flour desirable for biscuit making.

6. **Future Research:**

Problem shooting as a result of compositional variations in flour are very common at various bakery industries. Seasonal changes in wheat kernels are bound to occur and unavoidable. The future research will produce solutions by relating chemical properties as cause of problem shooting and how to modify four accordingly.

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