Effects of Fermentation Time, Inherent Flour Strength, and Salt Level on Extensigraph Properties of Full-Formula Remix-to-Peak Processed Doughs[1]

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ABSTRACT

The effects of fermentation time and salt level on the extensigraph properties of five flours of varying inherent strength processed by the remix-to-peak baking procedure were determined. Increasing fermentation time from 0 to 285 min resulted in relatively linear decreases in extensigram length, maximum height, and area at all salt levels (0.5, 1.0, 2.0, and 3.0%) and for all flour types. Changes in extensigraph properties during fermentation were strongly influenced by flour type and salt level. Flours of higher inherent strength and higher levels of salt increased values for length, maximum height, and area at all fermentation times and reduced the rate of decrease in these properties during fermentation. Salt level and fermentation time had little effect on the ratio of length (extensibility) to maximum height (resistance) with the inherently strong flour types with good baking quality. In contrast, ratios for the inherently weak flour types of poorer baking quality were very sensitive to both salt level and fermentation time.

Studies of the physical properties of wheat flour doughs have been a major contributing factor in our present understanding of the effects of flour type, processing conditions, and ingredient effects upon bread-making quality. However, the vast majority of these publications have referred to unleavened doughs. In contrast, relatively few studies are available concerning the physical properties of leavened doughs.

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Studies by Bailey and LeVesconte (1924) showed that the extensibility of leavened doughs stretched on a Chopin Extensimeter increased with prolonged mixing, increasing fermentation time and decreasing pH. Similarly, Bohn and Bailey (1937) showed that fermentation decreased and salt increased stress readings obtained when a mercury bath "tensiometer" was used. Their results indicated that the yield point and elastic properties of leavened doughs decrease and mobility increases during fermentation, while salt has an opposite effect. Using a different approach, Landis and Freilich (1934) showed that fermentation had a strong effect on dough colloidal properties. As fermentation time was increased, the time required to disintegrate a dough suspended in 1.0*M* sulfuric acid with an egg beater initially increased, then showed a rapid decrease. Changes in the disintegration time were closely correlated with loaf volume. These early studies supported the idea that fermentation of bread doughs by yeast had a "mellowing" effect.

More recent studies have tended to confirm and extend these earlier studies. Ikezoe and Tipples (1968) found that increasing the fermentation time of a flour-yeast-water sponge system reduced farinograph absorption, dough development time, and stability. Addition of bromate caused further weakening of the farinograph curve at longer fermentation times, whereas low levels of iodate had a strengthening effect. Using a Hoppler Consistometer, Prihoda et al (1971) found that the range of dough consistency for the same range of stress was smaller for fermented doughs than for unfermented doughs. Flours of varying strength gave similar ranking for both unfermented and fermented doughs. Using extensigraph techniques, Pizzinatto and Hoseney (1980) found that fermentation decreased the resistance to extension of cracker sponges, whereas salt increased resistance to extension. Similar results were also reported by Barber et al (1980), who used a sponge-and-dough process. Using a different approach, Matsumoto et al (1973) demonstrated that, during fermentation of a straight dough, internal dough pressure initially decreased, then increased. Oxidants tended to increase the internal pressure, whereas reducing agents reduced internal pressure. A later study showed that the doughs underwent a relaxation process following rounding, molding, and shaping (Matsumoto et al 1974).

Recently, we described a modified extensigraph procedure for measuring the stretching properties of fermented doughs (Kilborn and Preston 1982). Using processing conditions similar to the Remix baking procedure (Kilborn and Tipples 1981), large differences in the extensigraph properties of doughs varying in inherent flour strength were obtained. Increasing proof times of fermented doughs following sheeting and molding resulted in a dough-relaxation process similar to that obtained with unleavened dough while increasing bromate levels increased extensigram height and reduced extensibility. In the present article, the effects of salt and fermentation time on extensigraph properties of leavened doughs derived from five flours varying in inherent dough strength were examined.

MATERIALS AND METHODS

Flours

Three straight-grade flours and two composite flour blends of these were used in the present study. Two of the straight-grade flours were obtained by milling composite cargo samples of No. 1 CWRS-13.5 (Canada Western Red Spring, 13.5% guaranteed protein) and of Glenlea (No. 1 Canada Utility) wheats on the GRL Pilot Mill as described previously (Preston et al 1983). The third straight-grade flour was milled commercially (Reed Milling, Toronto) from CEWW (Canada Eastern White Winter) wheat. The two composite flours were obtained by blending equal weights of the No. 1 CWRS-13.5 with CEWW and the No. 1 CWRS-13.5 with Glenlea. Analytical and physical dough data for the flours are given in Table I.

Preparation and Stretching of Doughs

Doughs were prepared according to the remix-to-peak procedure as previously described (Kilborn and Tipples 1981). Ingredients included flour (200 g), yeast (3.0%), sucrose (2.5%), potassium bromate (15 ppm), ammonium phosphate-monobasic (0.1%), 60° L malt syrup (0.6%). For each flour, the optimum water absorption as determined by assessment at panning after the standard 165-min fermentation time, was used for all fermentation times. Salt levels used included 0.5, 1.0 (standard level), 2.0, and 3.0%.

For processing before stretching, ingredients were mixed for 3.5 min at 135 rpm in a GRL-200 mixer, rounded, and then fermented at 30° C. Fermentation times used were 0, 45, 105, 165 (standard procedure), 225, and 285 min. Following fermentation, doughs were remixed to peak consistency at 135 rpm in the GRL-200

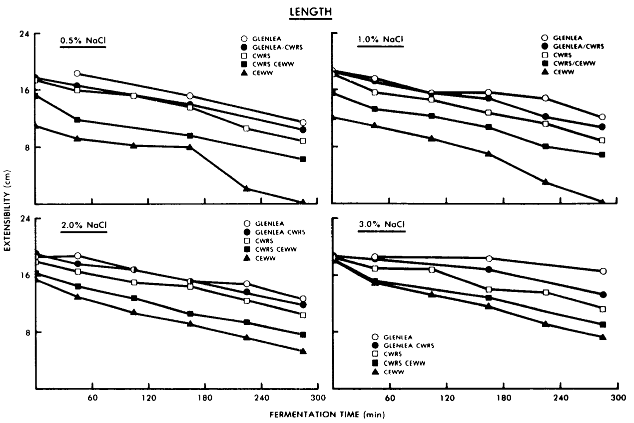

Fig. 1. Effects of fermentation time, flour type, and salt level on extensigraph lengths of full-formula remix-to-peak processed doughs.

TABLE I
Analytical, Physical Dough, and Remix-to-Peak Baking Data for Flours of Varying Inherent Strength[a,b]

	CEWW	CEWW:CWRS[c]	CWRS	CWRS:Glenlea[c]	Glenlea
Analytical					
Protein (%)	8.7	10.7	12.7	12.2	11.7
Ash (%)	0.46	0.43	0.43	0.46	0.50
Starch damage (units)[d]	4	18	31	35	38
Farinograph					
Absorption (%)	52.0	56.8	64.4	...[e]	...[e]
Dough development time (%)	1.00	2.50	5.25	...	...
Extensigraph					
Length (cm)	15.0	20.5	21.5	22.0	25.0
Height (BU)	135	345	415	640	720
Area (cm^2)	30	105	125	215	245
Remix-to-peak[f]					
Loaf volume (cc)	440	680	840	855	900
Absorption (%)	53	58	63	63	64
Mixing time (min)	1.5	2.3	3.0	3.6	6.4

[a] All data reported on 14.0% moisture basis.
[b] CWRS = Canada Western Red Spring; CEWW = Canada Eastern White Winter.
[c] 1:1 blend (wt/wt).
[d] Farrand units.
[e] Standard farinograph speed (64 rpm) below critical speed requirements (Kilborn and Tipples 1972). At 94 rpm, Glenlea had a dough development time of 8.0 min and a 61.5% absorption level (600-Brabender unit line).
[f] Performed under standard conditions (1.0% salt, 165 min fermentation).

mixer, divided into two equal pieces, rounded, and given an intermediate proof of 25 min at 30° C. Doughs were then sheeted and molded to a length of 152 cm (150% of standard extensigraph dough size). The molded doughs were then clamped into the modified extensigraph holders and proofed at 30° C for the standard 55-min proof time before stretching on the extensigraph as previously described (Kilborn and Preston 1982). For each treatment, four sets of duplicate doughs were used. Statistical analyses were performed on the Canada Department of Agriculture central computer system, using methods as outlined by Steel and Torrie (1980).

RESULTS

The modified extensigraph procedure described previously (Kilborn and Preston 1982) allows the measurement of the stretching properties of fermented doughs processed in a manner similar to a given baking procedure. In the present study, the effects of salt level, fermentation time, and inherent flour strength on the extensigraph properties of fermented doughs were investigated, using the processing conditions for the remix-to-peak baking procedure (Kilborn and Tipples 1981). The procedure was chosen because it is commonly used in Canadian wheat-testing programs, and, at the bromate level used (15 ppm), oxidation response is optimized over a wide range of processing conditions and flour types (Irvine and McMullen 1960). This latter factor, which is associated with the ability of remixing to neutralize the "excess bromate" effect (Freilich and Frey 1939), precludes the need to adjust bromate levels to obtain optimum baking response.

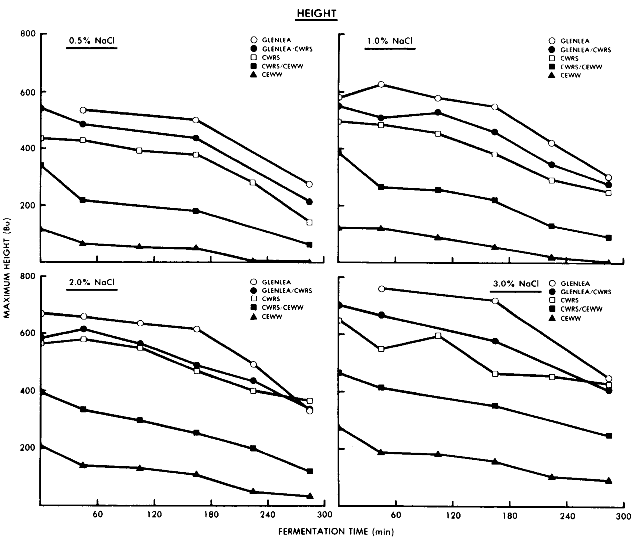

Fig. 2. Effects of fermentation time, flour type, and salt level on extensigraph maximum heights of full-formula remix-to-peak processed doughs.

The wide range of inherent strength of the flours chosen are evident from the farinograph, extensigraph, and remix-to-peak dough-mixing requirement data shown in Table I. The CEWW wheat flour had weak dough properties, as evidenced by the short farinograph and remix-to-peak dough-development time and the small extensigram area. In addition, the flour had a low starch-damage level and a low protein content. Normally, flours of this wheat class are used for the production of cookies, cakes, and other "soft" wheat products. The CWRS wheat flour had strong dough properties, as evidenced by the fairly long farinograph and remix-to-peak dough-development times and large extensigram area. This class of wheat is very well-known for its high bread-making quality. Glenlea, which is normally used as a blending wheat, had very strong dough properties, as shown by the very large extensigram area and long remix-to-peak requirements. The inability of the farinograph to develop Glenlea at standard speed (64 rpm), due to high critical-speed requirements (Kilborn and Tipples 1972), also emphasizes its very strong dough properties. At 92 rpm, a farinograph dough-development time of 8.00 min was obtained. The other two flours obtained by blending equal weights of CEWW with CWRS and CWRS with Glenlea gave doughs having strength properties intermediate to the parent flours.

Doughs from each of the flours varying in inherent dough strength were processed at constant absorption before stretching for all salt (0.5, 1.0, 2.0, and 3.0%) and fermentation (0–285 min in 45-min intervals) treatments. The absorptions chosen (Table I) were those required to give optimum handling properties at panning, using standard remix-to-peak baking conditions (165 min of fermentation, 1.0% salt). However, the CWRS wheat flour was also used to study the effects of absorption on extensigraph properties. All doughs were proofed 55 min before stretching. This proof time, which is normally used with the remix-to-peak procedure, allowed the fermented doughs to undergo relaxation following makeup, as previously shown (Kilborn and Preston 1982).

Effects of Fermentation, Inherent Dough Strength, and Salt on Extensigram Length

At all salt levels, extensigram lengths for each flour type decreased with increasing fermentation time (Fig. 1). Decreases almost always appeared to be linear with time. This was confirmed by a statistical linearity test. F-tests of the data also showed a significant ($P<0.005$) quadratic term in the equation. The extent of these decreases, however, were dependent both on inherent dough strength and on salt level. This is demonstrated in Table II, which shows analysis of variance (ANOVA) results. All treatments had highly significant effects ($P<0.005$). Interaction effects were also significant.

With no bulk fermentation, extensigram lengths of full-formula doughs generally decreased as inherent flour strength decreased (Glenlea < Glenlea:CWRS < CWRS < CWRS:CEWW < CEWW) at all salt levels (Fig. 1). Furthermore, as fermentation time was increased, changes in extensigram length were least evident with the strongest flours and became very evident as inherent flour strength

TABLE II
ANOVA for the Effects of Variety, Fermentation Time, and Salt level on Extensigraph Properties

Source		Length		Height		Area	
	DF[a]	MS[b]	F[c]	MS	F	MS	F
Variety (V)	4	981.3	1,377.3	3,109,070.4	3,050.1	111,396.2	3,651.2
Fermentation (F)	2	1,746.3	2,450.9	1,892,183.0	1,856.3	115,980.9	3,801.4
Salt (S)	3	237.6	333.5	656,432.5	644.0	29,063.6	952.6
V × F	8	16.7	23.5	64,598.7	63.4	5,820.2	190.8
V × S	12	18.3	25.8	12,672.9	12.4	1,184.8	38.8
F × S	6	9.3	13.0	6,370.8	6.3	524.8	17.2
V × S × S	24	3.1	4.4	5,278.2	5.2	192.6	6.3
Error	420	0.7	···	1,019.3	···	30.5	····

[a] Degrees of freedom (each of eight doughs treated as replicate).
[b] Mean square.
[c] F = test.

decreased. For example, with 1.0% salt, the very strong Glenlea flour showed a 35% decrease in length after 285 min of fermentation, while the weaker CWRS:CEWW flour blend showed a 57% decrease. The very weak low-protein CEWW had little fermentation tolerance and could not be stretched after 285 min.

As salt levels were increased from 0.5 to 3.0%, extensigram lengths of nonbulk fermented doughs for all five flours increased. These increases were much greater with the doughs from the weak flours. In fact, the large differences evident between the flour types at lower salt levels (0.5 and 1.0%) were not readily apparent with 3.0% salt. These results are not surprising in view of previous studies by Fisher et al (1949). Using unleavened doughs, these authors showed that the addition of salt increased extensigram length and reduced differences between wheat flours varying in inherent dough strength.

As salt levels were increased, the effects of fermentation on extensigram length became less evident. With 3.0% salt, changes in lengths between doughs fermented for 0 and 285 min decreased approximately 10% less than with 0.5% salt for most varieties and 40% less for the weak CEWW flour. However, differences were still evident between the five flour types at the high salt level.

Effects of Fermentation, Inherent Dough Strength, and Salt on Extensigram Height

The effects of fermentation time, inherent dough strength, and salt level on extensigram heights are shown in Fig. 2. ANOVA results (Table II) showed that all three treatments gave highly significant effects ($P < 0.005$). As with extensigram length, increasing fermentation time resulted in decreased extensigram heights for each flour type at all salt levels. However, changes in height showed less linearity with time than those for length, although this linear relationship was still highly significant ($P < 0.005$).

With no bulk fermentation (Fig. 2), large differences were evident in maximum extensigram heights between flour types at all salt levels. As expected, higher curves were obtained from flours with the greatest inherent dough strength. During fermentation, doughs from the stronger flour types (Glenlea, Glenlea:CWRS, CWRS) showed much greater tolerance (smaller percent decrease in extensigram height) than the weaker flour types (CWRS:CEWW, CEWW). With the former flour types, large decreases in height

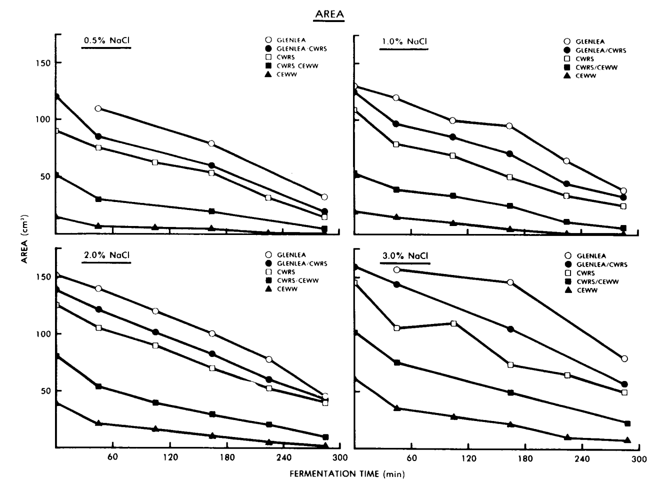

Fig. 3. Effects of fermentation time, flour type, and salt level on extensigraph areas of full-formula and remix-to-peak processed doughs.

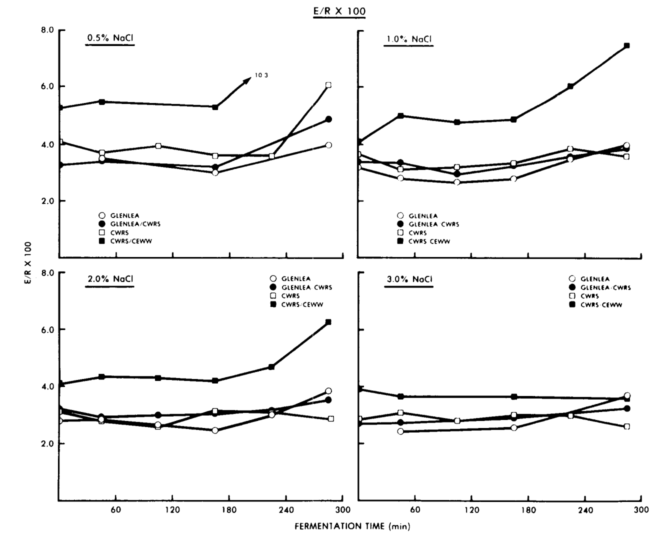

Fig. 4. Effects of fermentation time, flour type, and salt level on extensigraph E/R × 100 values of full-formula remix-to-peak processed doughs.

TABLE III
Effects of Water Absorption Level on Extensigraph Properties of Full formula remix-to-peak CWRS Doughs[a,b]

Salt Level (%)	0-Min Fermentation Absorption (%) 65	61	165-Min Fermentation Absorption (%) 65	61	285-Min Fermentation Absorption (%) 65	61
ΔEL (cm)[c]						
0.5	0.6	0.0	0.1	−0.2	0.9[d]	0.4
1.0	−0.9[d]	−1.0[d]	0.8[d]	0.0	−0.2	−1.9[d]
2.0	0.5	−0.5	0.7	0.3	0.7	0.0
3.0	1.2[d]	−0.5	0.3	−0.2	−0.6	−0.9[d]
ΔEH (BU)[c]						
0.5	−56[d]	23	−47[d]	15	29	63[d]
1.0	6	29	5	15	−23	125[d]
2.0	−47[d]	46[d]	−37[d]	−2	−25	62[d]
3.0	−68[d]	13	−36[d]	26	33	20
Δ (cm)[c]						
0.5	−10.6[d]	7.9[d]	−3.4	0.0	5.1[d]	5.9[d]
1.0	−4.6	2.6	2.4	−0.3	−3.6	−5.3[d]
2.0	−11.5[d]	9.6[d]	0.7	−1.1	2.3	8.7[d]
3.0	−6.4[d]	−0.5	−2.0	−6.8[d]	0.0	−1.7

[a] Results based on average of eight tests.
[b] Results represent differences between values obtained at specified absorption minus those obtained at 63% absorption.
[c] ΔEL = difference in extensigraph length; ΔEH = difference in extensigraph height; ΔEA = difference in extensigraph area. BU = Brabender unit.
[d] Significant difference at $P = 0.05$.

were not generally evident until fermentation times exceeded 185 min, whereas with the latter flour types decreases were more evident with shorter fermentation times.

As shown previously for unleavened dough (Fisher et al 1949), salt increased the extensigram heights of nonbulk fermented doughs from all flour types. Increases, on a percent basis, were more evident with the weaker flours, although, in contrast to extensigram length, large differences were still evident between flours of varying inherent strength at high salt levels. Increasing salt levels increased fermentation tolerance, as evidenced by the decreased rate of change of height with fermentation time as salt was increased from 0.5 to 3.0% (Fig. 2). With the two lower salt levels, the rate of change of height with fermentation time at 285 min decreased as inherent flour strength increased. However, at higher salt levels (2.0 and 3.0%), the CWRS flour showed a lower rate of change when compared to the inherently stronger Glenlea and Glenlea:CWRS blend. This is an interesting result in that it indicates that, under certain conditions (ie, high salt), fermentation tolerance may not necessarily relate to inherent dough strength as measured using unleavened dough (Table I).

Effects of Fermentation, Inherent Dough Strength, and Salt on Extensigram Area

The effects of fermentation time, inherent dough strength, and salt level on extensigram area were, as expected, closely related to the corresponding effects of these factors on extensigraph length and height (Fig. 3, Table II). At all salt levels, increasing fermentation time resulted in decreases in extensigram area for all flour types in a fairly linear and statistically significant ($P<0.005$) manner (Fig. 3). With no bulk fermentation, extensigram areas showed large increases as inherent flour strength increased at all salt levels. Although differences between flour types were less evident at longer fermentation times, doughs with high inherent dough strength showed smaller proportionate (percent) decreases in area. At the two lower salt levels, the very strong Glenlea and Glenlea:CWRS blend flours showed the smallest percent changes after 285 min of fermentation, while at the higher salt levels, differences between Glenlea and CWRS were less evident. As with length and height, higher salt levels resulted in increased areas and reduced rates of change of areas with fermentation time.

Effects of Fermentation, Inherent Dough Strength, and Salt on the Ratio of Extensibility to Resistance

With the three strongest flours (Glenlea, Glenlea:CWRS, CWRS) the ratio of extensibility to resistance ($E/R \times 100$) value did not show large changes with fermentation time. Furthermore, corresponding treatments for each of these flours generally resulted in similar values. However, $E/R \times 100$ values for the two weaker flours (CWRS:CEWW, CEWW) were much more variable. With the exception of the 3.0% salt treatment, values for the CWRS:CEWW flour were much higher than those obtained for the stronger flours. The weak low-protein CEWW wheat generally gave very high values (7.2–27.8) at the three higher salt levels and low values (less than 1.6) for the lowest salt level (data not shown).

Generally, salt did not have a large effect on values of $E/R \times 100$ with the stronger flours, although, at the lowest salt level, values increased at longer fermentation times. With the weaker flours, increasing salt level reduced the rate at which values of $E/R \times 100$ increased with increasing fermentation time.

Effects of Water Absorption on Extensigraph Properties

In the present study, doughs for each flour type were processed at constant absorption levels for all treatments (salt level, fermentation time). Although these absorptions represented optimums for dough-handling properties based upon standard remix-to-peak conditions (1.0% salt, 165 min of fermentation), doughs processed with minimum or maximum fermentation times appeared to require up to +2% or −2% water, respectively, for optimum dough-handling properties. Previous studies have shown that suboptimum dough-absorption levels can cause changes in viscoelastic properties that can affect bread quality (Webb et al 1970, El-Dash 1978). Therefore, experiments with the CWRS wheat flour were conducted to determine the extent to which suboptimum dough absorptions affected the extensigraph results. For these experiments, CWRS dough absorptions were varied from 65 to 61% for each salt level, using fermentation times of 0, 165, and 285 min. In most cases, increasing or decreasing absorption by 2% did not significantly ($P<0.5$) affect extensigram length (Table III). However, increasing absorption by 2% generally led to significant decreases in height with 0 and 165 min of fermentation and to decreases in area with 0 min of fermentation. Decreasing absorption by 2% resulted in significant increases in height, with 285 min of fermentation and generally resulted in increases in area. Similar relationships between extensigraph properties and water absorption of fermenting doughs were shown previously by El-Dash (1978).

We conclude from the above results that, with short and long fermentation times, constant suboptimum absorption levels would probably have greater effects on extensigraph properties than would be obtained had doughs been adjusted to optimum absorption based on handling properties. However, comparison of the results obtained at constant absorption with those obtained at "optimized" absorption clearly showed that the effects of fermentation and salt level were much greater than that of absorption over the ranges studied.

CONCLUSIONS

The present study shows that inherent flour strength, salt level, and fermentation time have large significant effects upon the extensigraph properties of leavened doughs processed by a modified straight-dough (remix-to-peak) method. The effects of inherent flour strength and salt level upon fermented dough extensigrams were similar to those shown previously with unleavened dough systems (Fisher et al 1949). In almost all cases, dough prepared from flours with the strongest inherent strength and the highest salt levels had the greatest extensibilities, resistance to extension, and areas at all fermentation times. Previous studies by Pizzinatto and Hoseney (1980) showed similar effects of salt on extensigraph properties, using fermented cracker sponges.

Increasing fermentation time resulted in overall decreases in apparent dough strength as evidenced by decreasing extensibilities (length), resistance to extension (height), and areas. These results support data obtained by Pizzinatto and Hoseney (1980) with fermenting cracker sponges but conflict with the results of Barber et al (1980). In the latter study, doughs prepared by a sponge-and-dough procedure showed increased resistance to extension with longer fermentation times (rest periods). However, work imparted between rest periods before stretching the dough may have influenced these results.

Changes in extensigraph properties during fermentation were less evident with flours of stronger inherent strength. Increasing salt levels had a similar effect. These results are consistent with the well-known effects of flour type and salt level on fermentation tolerance during breadmaking.

Perhaps the most interesting and unique findings in the present study involve the linear relationships between the various extensigraph properties and fermentation time and the data obtained for the relationship between extensibility and resistance ($E/R \times 100$). The linear decrease in extensigraph length, height, and area with fermentation time occurred with all flour types and at all salt levels, although these treatments did affect the rate of decrease (Figs. 1–3). Presently, the reasons for the linearity of these decreases are not known, although it may be related to the effects of the gradual lowering of the pH during fermentation due to the production of lactic acid and other acids by the yeast (Pizzinatto and Hoseney 1980) or to the time-dependent "development" of the gluten due to internal gas pressure (Matsumoto et al 1973; Preston and Kilborn 1982). In contrast, $E/R \times 100$ values for the three "strongest" flour types (Glenlea; Glenlea: CWRS; CWRS) were similar (3.0–4.0) and showed little change with fermentation time and salt level. The "weaker" CWRS:CEWW flour showed rapid increases at longer fermentation times and lower salt levels, while the "weakest" CEWW flour gave very low values with 0.5% salt at all fermentation times and very high values with the high salt levels.

Thus it appears that, in spite of changes in dough extensibility and resistance to extension due to fermentation and salt level, doughs from flours of high inherent strength maintain fairly constant E/R ×100 ratios, whereas doughs from "weaker" flours can show a wide range of variability. Previous studies in our laboratory (Preston et al 1984)[3] have shown that the three "stronger" flours produced high-quality bread over the range of conditions used in the present study, while the CWRS:CEWW flour produced good bread only at shorter fermentation times and the CEWW flour produced poor-quality bread under all conditions. Thus, the ratio of dough extensibility to resistance to extension rather than the individual parameters may be more closely related to bread quality.

[3]Preston et al. 1983. Unpublished data.

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