Baking and Related Properties of Wheat-Oat Composite Flours

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ABSTRACT

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Composite blends of wheat and oat flours were evaluated in terms of their bread- and cookie-making quality. Two different oat flours were investigated in composites containing up to 25% oat flour. Dough development time, dough strength, centrifuge water retention, and loaf volume decreased, and mixing tolerance increased as the amount of oat flour in the composite increased. Slight differences existed between the two oat flours in the magnitude of effects, pasting behaviors, and loaf-volume response to oxidants and sodium stearoyl-2-lactylate. There was no significant difference in the rate of gas production of wheat flour and composite doughs. Cookie spread factors increased with increasing amounts of roller-milled oat flour in the formulation, whereas those of Quaker oat flour composites remained constant.

Oats, the third largest cereal crop in Canada and the fifth largest in the world, is an important grain for livestock and poultry feed. It is an excellent food grain because of the high nutritional quality of its protein. Until now, only 7% of the total oat production has been used for human consumption, mainly as rolled oat groats or oat flour (Cluskey et al 1979, USDA 1979).

Several investigators have used oat flour or its components in breadmaking. Hoseney et al (1971) demonstrated that reconstituted loaves containing oat starch had high water absorption and poor breadmaking characteristics. Pomeranz et al (1971) used 15% commercial oat hulls in baking studies and found that this reduced baking water absorption and loaf volume, but increased mixograph mixing time. D'Appolonia and Youngs (1978) reported that oatmeal bran and high oat protein concentrate increased farinograph absorption and produced doughs with good stability but decreased loaf volume. Oat proteins ("oat gluten") do not complement wheat gluten since they are only slightly cohesive and entirely inelastic (Cunningham et al 1955). Hence, incorporation of oat flour or oat protein into wheat dilutes wheat gluten, thereby producing a reduction in loaf volume. However, investigation by Jones and Hutchinson (1945) showed that suitable dry heat treatment of oat groats was an effective and practical means of counteracting the deleterious effects of ground groats blended with wheat flour.

Relatively few investigations have been made on the breadmaking properties of wheat-oat composite flours. This article contains the results of a study on composites prepared from two different oat flours. Information on rheological characteristics of wheat-oat flour composite is important in the potential use of oat flour in baking.

MATERIALS AND METHODS

Materials

Descriptions of the flours used in this study, together with pertinent analytical data, are given in Table I. The commercial oat flour, Quaker Oat Flour (QOF), was obtained from Quaker Oats Company, Peterborough, Ontario. The second roller-milled oat flour (RMOF) was milled on a Buhler laboratory mill from groats of the cultivar Sentinel. The milling yielded four fractions—bran, first shorts, second shorts, and flour. Because the yield of the milled flour fraction was very low, it was combined with the second shorts fraction to give a cumulative extraction of 42% of the total oat groat as RMOF used in this study. The wheat flour was a commercial, brominated (15 ppm), all-purpose wheat flour. Composites were prepared containing 5, 10, 15, 20, and 25% (by weight) of the respective oat flours.

Mixograph Measurements

Mixing properties of wheat and wheat-oat composite flours were determined using 50 g of flour (14% mb) and constant water absorption (60%) by the electronic dough-recording procedure of Voisey et al (1966). Energy output was monitored over time by a chart recorder and digital integrator as described by Voisey et al (1967). Mixing tolerance and rate of dough development were calculated from the mixograph curve as described by Swanson and Johnson (1943). Maximum torques were obtained from the curves, and the areas under the curves (0–7 min of mixing) were measured with a planimeter. Reported results are the means from six replicate mixograms.

Pasting Properties of Composite Flours

Pasting properties of the wheat and oat flours and their composites (25%) were determined with the Ottawa Starch Viscometer (OSV) on 9% starch basis (w/w, db) and slurried in distilled water as described by Paton and Spratt (1981). The OSV was operated at a bowl speed of 200 rpm, a torque calibration of 50 cm N $\times 10^{-2}$ full-scale recorder deflection on the Y axis, a temperature calibration of 25–97° C on the X axis, and an initial water bath temperature of 60° C.

Breadbaking

Pup loaves were baked by AACC straight dough procedure, method 10-10 (AACC 1961) from the two blends of wheat and oat flours. The bread formula was: wheat flour blend (14% mb), 100 g; compressed yeast (Lallemand, Canada), 3.5 g; sugar, 3.3 g; shortening (Crisco, Proctor and Gamble, Canada), 3 g; salt, 1.7 g; Delquik 70 HS (a dough conditioner containing 68 ppm of ascorbic acid, 40 ppm of potassium bromate, and 12.5 ppm of cysteine –HCl, Ogilvie Flour Mills, Canada), 0.5 g; malt, 0.3 g; ammonium phosphate monobasic, 0.1 g; potassium bromate, 15 ppm; and water calculated to 60% absorption. Another series of breads was baked with the addition of 0.25, 0.5, 0.75, and 1% sodium stearoyl-2-lactylate (SSL). Doughs were mixed for 3.5 min in a National 100–200-g mixer (National Mfg. Co., Lincoln, NE). Rest time was

TABLE I
Analytical Data on Flours Used

Flour	Percent Protein[a] (N × 5.7)	Ash[a] (%)	Lipid[a] (%)	Crude Fiber[a] (%)	Amylase Activity (mDu)[b]	Free Fatty Acids (%)
Wheat	15.16	0.52	1.26	0.56	0.15	
Quaker oat[c]	13.85	1.91	8.01	1.96	0.13	0.66
Roller-milled oat	11.58	1.14	6.13	1.07	0.13	0.79
Oat (Sentinel)	14.93	3.07	3.40	12.56		

[a] Data on dry matter basis.
[b] Millidextrinizing units.
[c] Quaker oat flour (#1) is a commercial product obtained by hammermilling and sieving regular steel-cut groats so that 85% of the product passes through a U.S. 40-mesh screen (425 mμ).

60 min at 28°C and 85% relative humidity (rh). The fermented doughs were sheeted with a National Sheeter, molded in a SH-E-L molder (National Mfg. Co., Lincoln, NE), and panned. After a 90-min proof time at 28°C, the bread was baked for 25–30 min at 218°C in a reel rotating oven (National Mfg. Co., Lincoln, NE). Volumes of the cooled loaves were measured by rapeseed displacement.

In the study of the response of composites to oxidants, potassium bromate and Delquik were omitted from the bread formulation and were substituted by 75 ppm of ascorbic acid and varying levels of potassium bromate.

Cookies were baked from the two blends of wheat and oat flours, using the AACC (1969) cookie spread factor test (method 10–50D).

Analytical Procedures

The wheat and oat flours and their composites were analyzed for moisture, ash, fat, crude fiber, and protein content (N × 5.7) by AACC methods (1961). The second RMOF was milled (as-is) on a Buhler laboratory mill (type MLU-202) from groats of the cultivar Sentinel as outlined for soft wheat milling (method 26-20, AACC 1961). Free fatty acid content in oat flours was determined by the colorimetric method of Sahasrabudhe (1982).

Gas production in yeasted slurries of wheat and wheat-oat composites (25% substitution) was determined by AACC method 22-11 (1961). Ten grams of flour (14% mb) and 15 ml of water containing 0.60 g of sugar, 0.35 g of fresh bakers' yeast and 0.15 g of salt were placed in a pressure vessel that had been previously warmed to 30°C, and mixed. The gas produced was expressed as millimeters Hg pressure.

Water retention of wheat and composite flours was determined by the micro-centrifuge method of Miller (1968). Amylase activity was determined by the method of Mathewson and Pomeranz (1979). The statistical analysis of the data was performed as described by Duncan (1955).

RESULTS AND DISCUSSION

Mixograph Results

In general, an increase in concentration of oat flour in the composites decreased maximum torque, dough development, and area under the curves, whereas the mixing tolerance increased (Fig. 1). The rate of decrease was more pronounced in RMOF composites. Mixing tolerance of the RMOF composites was significantly higher than that of the QOF composites at all levels of substitution. The results indicate that the QOF and RMOF composites have considerably less flour strength but greater mixing tolerance than the wheat flour. The noted increase in mixing tolerance of the wheat-oat flour composites could result from the

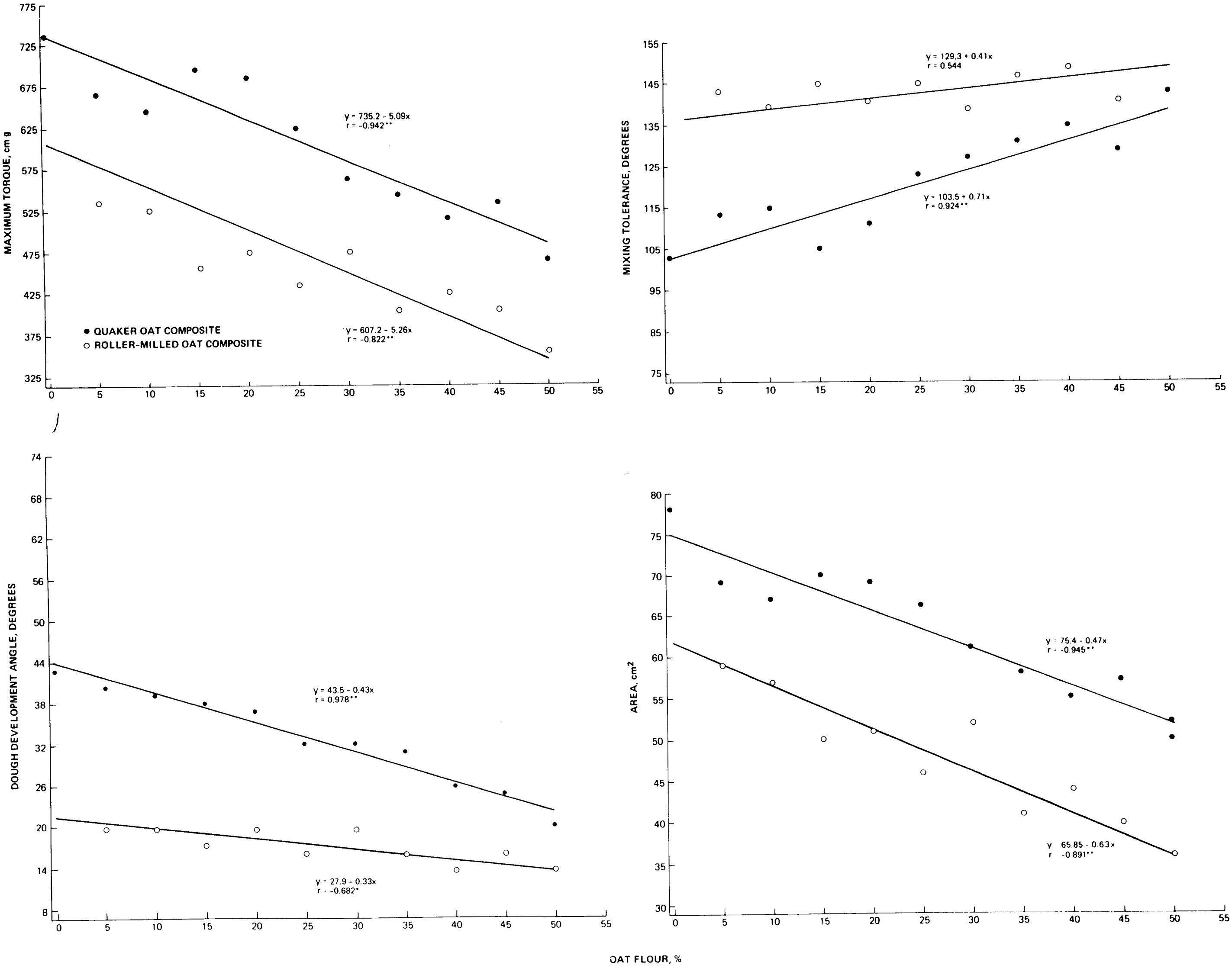

Fig. 1. Relationship between wheat flour substitution (%) by (●) Quaker oat flour or by (O) roller-milled oat flour and mixograph maximum torque, mixing tolerance, dough development, and area.

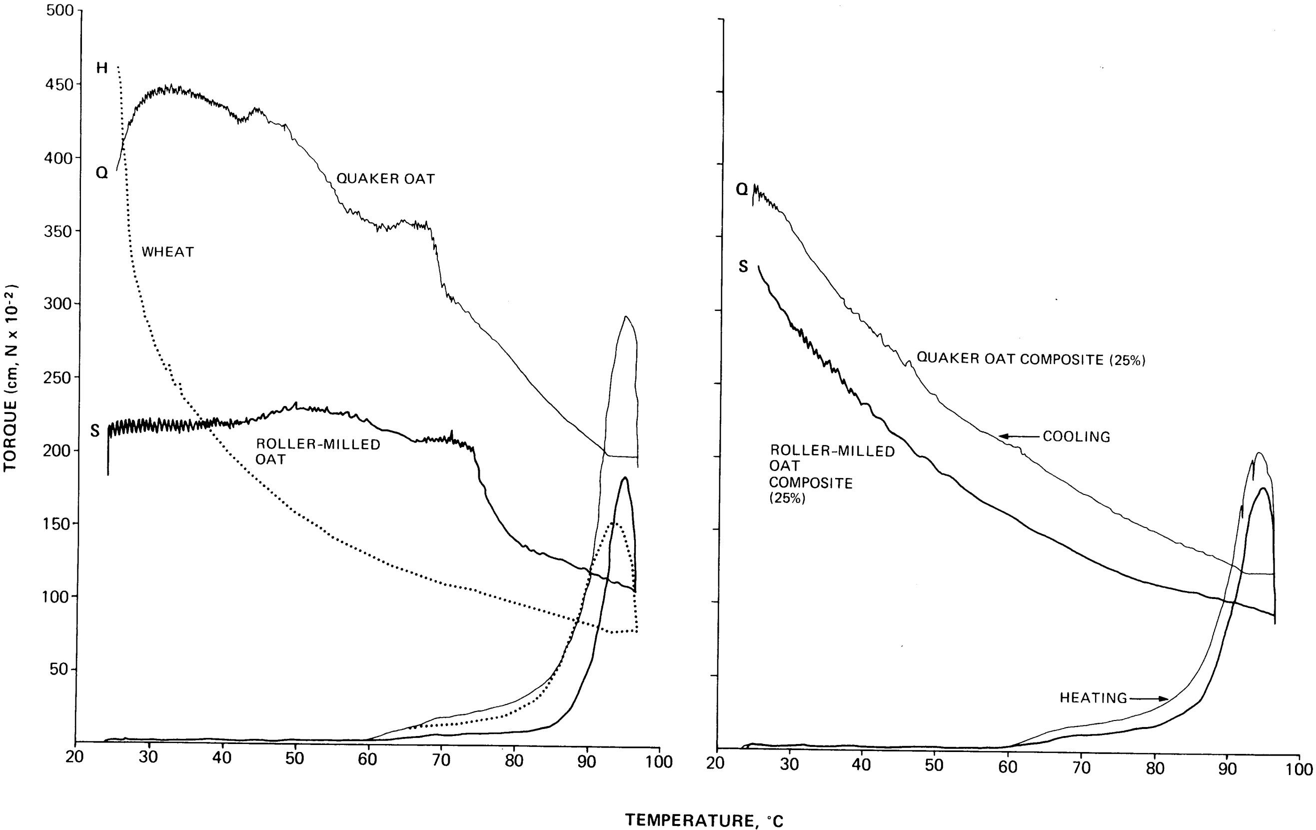

Fig. 2. Pasting curves for oat flours and wheat flour and their composites.

TABLE II
Pasting Characteristics of Flours

Flour	Initial Swelling (°C)	Peak Temperature (°C)	Peak Torque P (cm N × 10^{-2})[a]	Hold Torque H (cm N× 10^{-2})[a]	P/H[b]	Torque at 25° (cm N × 10^{-2})[a]
Wheat	59	93.0	175	77.5	2.26	470
Quaker oat	59	94.5	295	200	1.48	400
Roller-milled oat	62	94.5	182.5	105	1.74	215
25% Quaker oat flour composite	58	94.0	205	120	1.71	385
25% Roller-milled oat flour composite	59	94.5	180	95	1.89	330

[a] N = Newton.
[b] Breakdown ratio.

higher lipid content of oats (Pomeranz 1971) as well as from the weakening of the wheat gluten by the oat flour. The lower correlation coefficients for the RMOF composites indicate a lower degree of association between percent substitution and these mixing characteristics.

Pasting Properties of Wheat-Oat Flour Composites

The cooking or "pasting" behavior of the wheat and oat flours and of blends of the two at 25% substitution level is given in Table II. Peak viscosity of the oat flours was higher than that of the wheat flour, especially for the QOF. A rapid rise in viscosity was observed as the hot oat flour paste was cooled (Fig. 2), a plateau being observed at 75° C for RMOF and 45° C for QOF. The response of viscosity to temperature as the pastes cooled was slower for RMOF, whereas a very rapid rise in viscosity was observed for QOF. This difference in viscosity could reflect enzyme activity or starch properties of oat flours in combination with wheat flour. Both oat flours had the same amylase activity, and therefore the difference in viscosity cannot be attributed to this factor, as is generally the case in cereal flours. Peak torque for wheat, RMOF, and a 25% RMOF composite was similar to and lower than that of QOF. Steam treatment of oats has been found to increase the formation of mucilaginous compounds, thereby producing an increase in viscosity (Shabakov et al 1980), which might explain the higher viscosity of QOF.

Gas Production of Yeasted Slurries

Essentially the same amount of yeast fermentables, as indicated by gas production, was present in the wheat-oat composites as in the control wheat flour (Fig. 3). However, gas production after 2 hr was slightly higher in the composites than in the control. Consequently, loaf volume-depressing effects of oat flours seem to result from reduced gas retention rather than from reduced gas formation.

Water Absorption (Centrifuge Water Retention)

In general, an increase in the proportion of oat flour decreased the water absorption of the resulting composite (Fig. 4); the effect of QOF was somewhat less than that of RMOF, possibly because of the slightly higher protein content, the higher content of bran, and the effects of heat treatment in the manufacture of the QOF. Steam treatment of wheat is known to decrease cohesiveness and increase gel strength; hence, the ability of entrapping large amounts of water is increased (Schmidt 1981).

Breadbaking Results

The incorporation of either of the oat flours into the control bread formulation led to a progressive decrease in loaf volume with increasing content of oat (Fig. 5). Slight differences were apparent between the two oat flours, with 25% RMOF producing the largest volume-depressant effect.

Effects of SSL. The effects of SSL on the baking properties of the composites are shown in Fig. 5. SSL contributed only slightly to volume of composites of either oat flour; RMOF volumes equal to control were obtained at 5 and 10% levels, with SSL at about 0.5%. Many of the small effects of SSL were not statistically significant, indicating that the doughs of these composite flours were not responsive to the customary dough stabilization and strengthening effects of this particular lipid conditioner. Bean et al (1976) also noted a similar ineffectiveness of SSL with storage-deteriorated flours and suggested that lipolytic enzymes might hydrolyze SSL as well as native flour lipids. However, Bean et al (1977) reported that ethoxylated monoglyceride was effective in overcoming the loaf volume-depressing effects of deteriorated flours. Therefore, investigations of other dough improvers may be warranted in the study of oat composites.

Effects of Oxidants. Figure 6 shows the loaf volume response of QOF and RMOF composites (5–20% substitution level) to increased levels of oxidants. Ascorbic acid (75 ppm) in addition to oxidants already present in the commercial wheat flour generally increased loaf volume for all composites, the increase being much more pronounced with RMOF. Addition of increasing levels of bromate to ascorbic acid (75 ppm) produced a much smaller decrease in loaf volume of RMOF composites than for QOF composites. The RMOF composites have a higher bromate tolerance (except for 15% RMOF at 30:75 oxidant level) and higher oxidative requirements than the QOF composites. Generally, for each 5% increase in RMOF, $KBrO_3$ requirement rose by 5 ppm, a result similar to that of Jeffers et al (1978) with pea and soy flour and wheat blends. Kulp et al (1978) found that individually used oxidants were inferior to the combination of ascorbic acid and potassium bromate in soybread.

Effect of Increased Water Level on QOF. The doughs containing QOF were previously noted as being of higher consistency than those of RMOF because of higher water absorption. To determine whether the QOF doughs would respond to oxidants differently if the water level were increased, doughs containing the same levels of added oxidants were prepared at 60, 62.5, 65.0, and 69.5% absorptions. The results are shown in Fig. 7. Although the baking performance of all composites, including those with no added oxidant, was improved as water was increased to an optimum of 65%, the response of the doughs to oxidants was not significantly altered except at 65%, where bromate showed an enhanced tolerance to overoxidation.

The baking results indicate an interesting difference between the effects of oxidant on RMOF and QOF, and suggest that additional studies related to oxidant requirements of composite flours are required to determine whether improved volume from composite flours is possible, depending on the nature of the nonwheat constituents employed in the composite formulation.

Cookie Baking

Cookie spread factors of cookies baked from RMOF increased progressively as its level in the formulation increased from 5 to 25% (Table III). However, cookie spread factor of QOF composites did not differ significantly from the wheat flour control, except at the 5% level of substitution. This difference may be due to the viscosity difference of the two oat flours as observed in the OSV, to the water absorption difference, as well as to the differences in their compositions.

The baking properties of these wheat-oat composite flours document the functionality of the two oat flours QOF and RMOF. The loaf-volume response of QOF and RMOF composites to baking was different. Many of the differences between RMOF and QOF may have been due to the amount of oat bran present in them. However, the present results showed no such evidence, because substitution of wheat flour by RMOF (1.07% crude fiber, Table I) resulted in a greater loaf volume-depressing effect than substitution by QOF (1.96% crude fiber, Table I) at similar concentrations. Neither can the observed differences in loaf volume be related to lipases, because the RMOF was nearly devoid of the bran fractions where oat lipases are localized (Sahasrabudhe 1982).

The loaf volume-depressing effect of the oat flours (RMOF and QOF) was similar to that reported by D'Appolonia and Youngs (1978) for oat protein concentrates (about 20 and 37–46%) reduction in loaf volume of the wheat flour control at 10 and 20% substitution, respectively). Oat starch was also reported to produce a loaf volume-depressing effect (Hoseney et al 1971). There may be some important interactions between wheat flour (endosperm fractions) and oat endosperm fractions that result in loaf volume depression. Soy proteins and wheat proteins were reported to form complexes because of protein–protein interactions (Aidoo 1972). Similar complex formations due to interactions of oat and wheat proteins are possible because globulin is the major protein of both soy and oat flours. Additional studies will be required to elucidate the role in loaf-volume development of lipids contributed by the oat flours, the interactions of dough constituents with oat proteins and other oat flour components, and the importance of these interactions in breadbaking of composite flours.

CONCLUSIONS

Substitution of wheat flour by either QOF or RMOF in bread dough resulted in a linear decrease in strength and stability of the doughs from the composites. The dough made from QOF composites was stronger and more stable than that made from RMOF composites. The stability of QOF composites was also

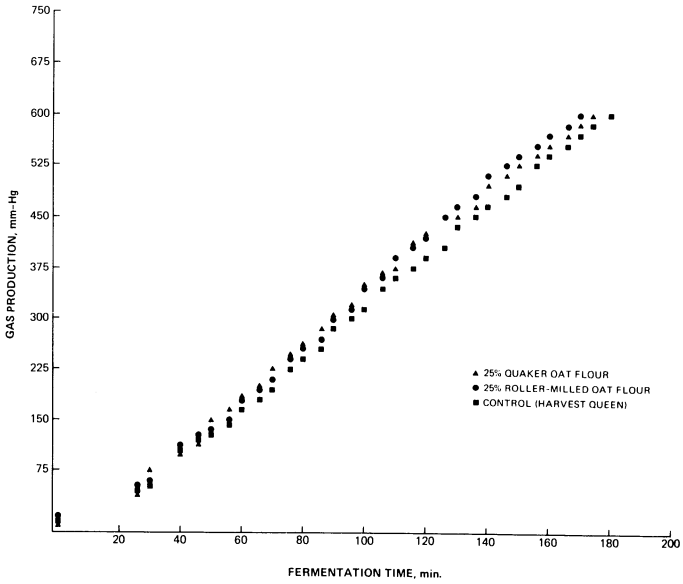

Fig. 3. Gas production (mm Hg) by yeasts in slurries of (■) wheat flour, (▲) Quaker oat flour composite (25%), and (●) roller-milled oat flour composite (25%) fermented at 30°C.

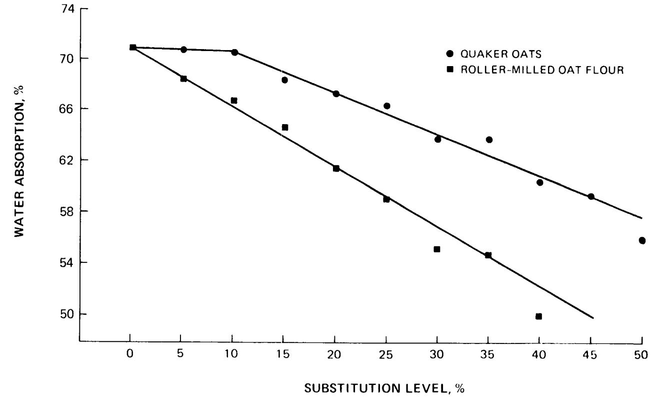

Fig. 4. Relationship between percent wheat flour substitution and water retention by (●) Quaker oat flour or by (■) roller-milled oat flour.

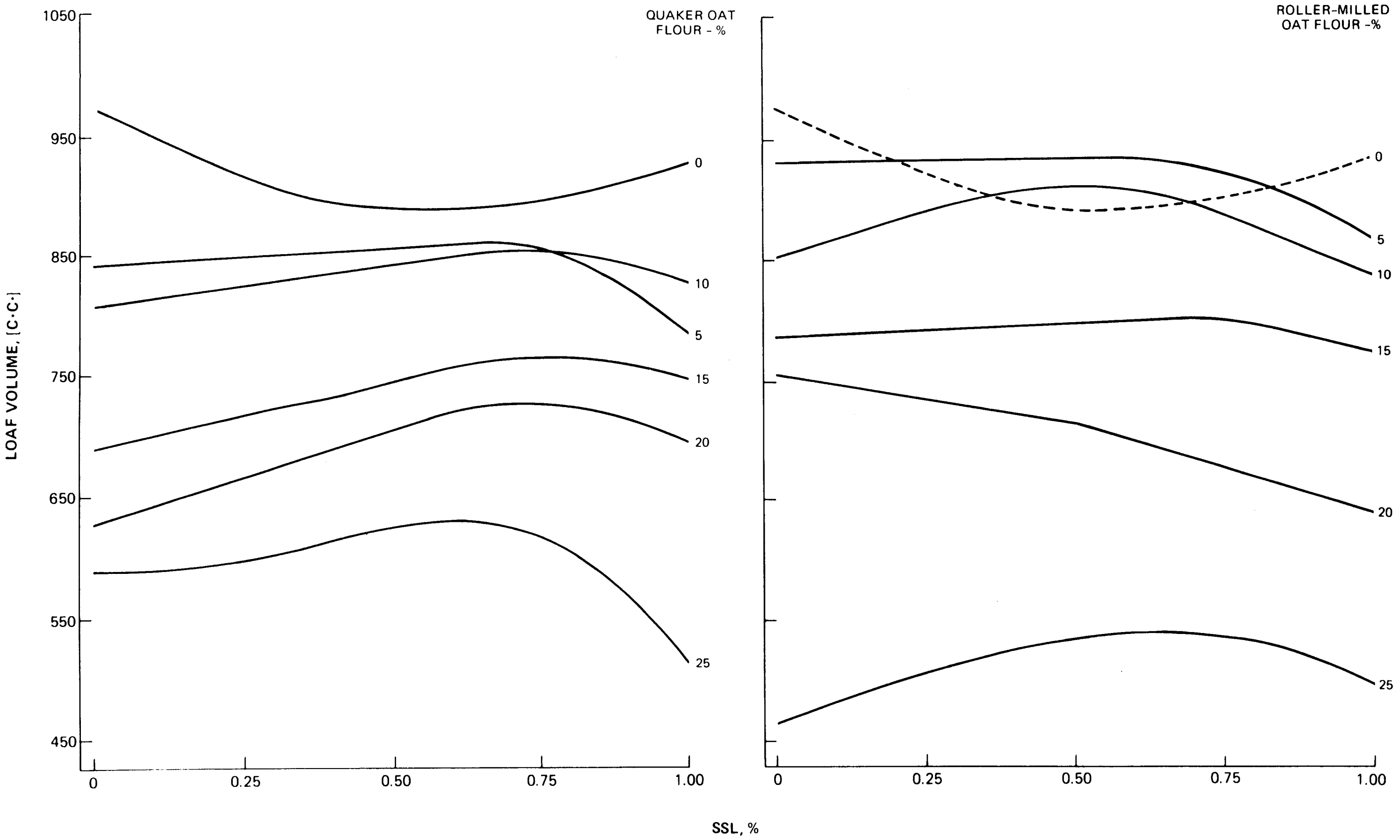

Fig. 5. Loaf volume response of composites to increasing levels of sodium stearoyl-2-lactylate (SSL).

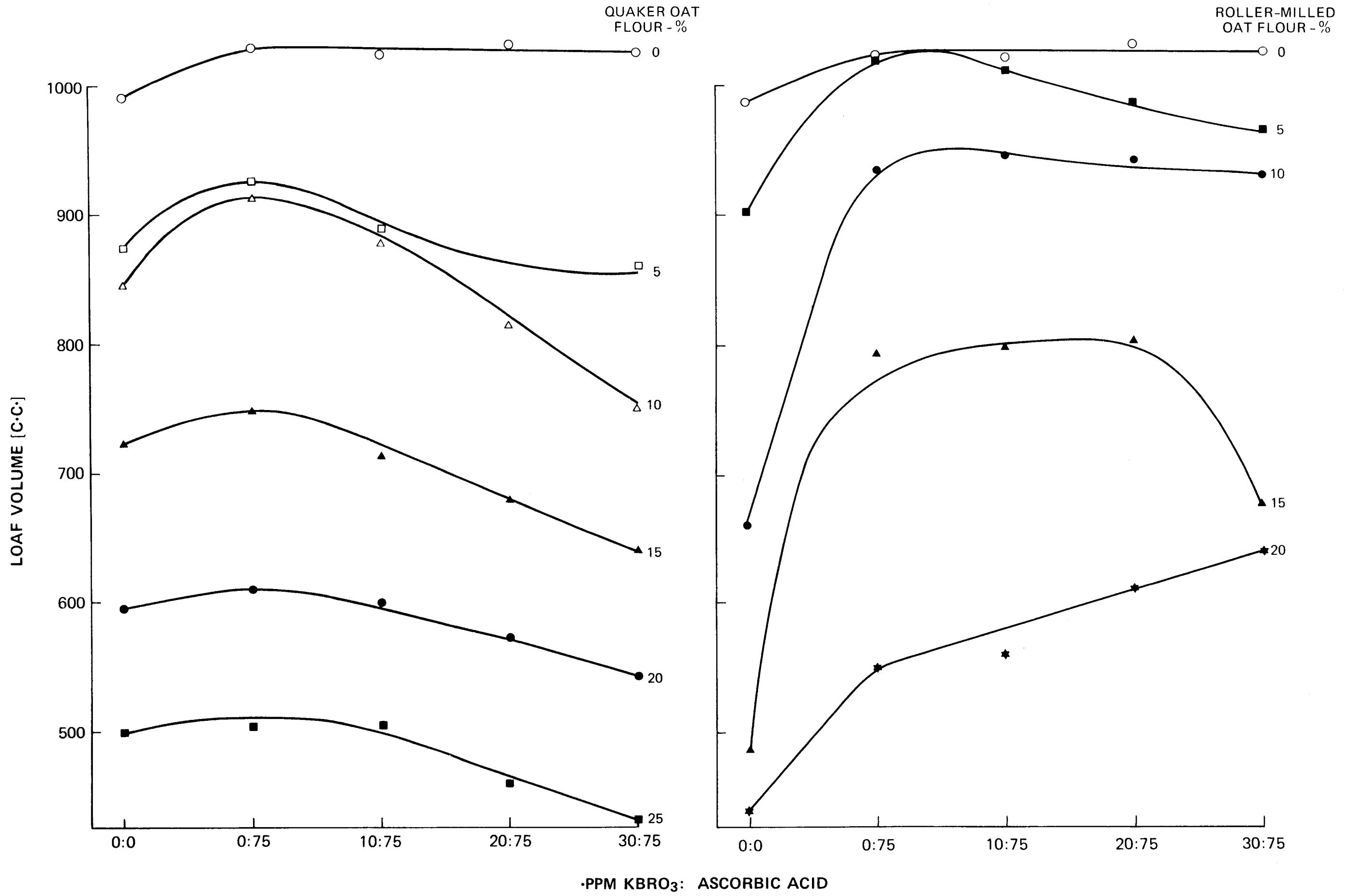

Fig. 6. Loaf volume response of composites to increasing levels of oxidants.

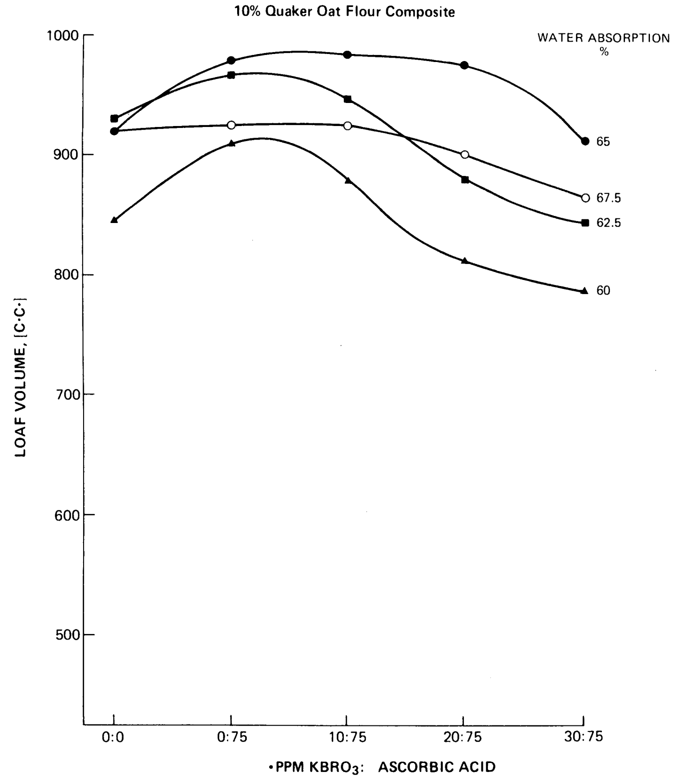

Fig. 7. Loaf volume response of 10% Quaker oat flour composite to increasing levels of oxidants at different water absorption.

TABLE III
Spread of Cookies from Wheat-Oat Composite Flours

	Cookie Spread (W/T)[a]	
Oat Flour (%)	**Quaker Oat Flour**[b]	**Roller-Milled Oat Flour**
0	6.54 b	6.79 e
5	8.56 a	7.11 d
10	6.97 b	7.33 c
15	7.05 b	7.66 b
20	6.88 b	7.69 b
25	7.22 b	8.01 a

[a] W/T = Ratio of width to thickness.

[b] Lowercase letters denote significant differences ($P < 0.05$).

reflected in their response to different concentrations of oxidants and SSL. Neither the oxidants nor the SSL produced any improvement in loaf volume of QOF composites. Loaf volume of the RMOF composites, especially at 5 and 10% substitution improved in response to oxidants and SSL. The RMOF composite may reach its optimum loaf volume potential, whereas the QOF composites cannot do so because of other factors such as dough viscosity.

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