THE UNIVERSITY OF MANITOBA

AN INVESTIGATION OF THE EFFECTS OF CHLORINE TREATMENT ON THE CAKE BAKING PROPERTIES OF TRITICALE FLOUR

by

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A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

DEPARTMENT OF FOODS AND NUTRITION

WINNIPEG, MANITOBA

MAY, 1971

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of Dr. W. Bushuk, Department of Plant Science, University of Manitoba for milling and supplying the Triticale flour, and Dr. E. D. Schilling of General Mills, Inc., Minneapolis, for treating the flour with chlorine.

The guidance supplied by Dr. G. F. Atkinson and Dr. B. Johnston of the Statistics Department, University of Manitoba in the analysis of the data was greatly appreciated.

Finally, the support and guidance of my advisor, Mrs. Marion Vaisey, in the planning and executing of the study and her assistance in coordinating this report is acknowledged.

ABSTRACT

Pertinent physical and chemical properties of Triticale flour, treated with chlorine gas at five levels, 0.2, 0.3, 0.4, 0.5 and 0.6 ml/g flour, were measured and compared to unchlorinated Triticale flour. With increasing chlorine treatment, a drop in flour pH occurred, and the alpha-amylase activity was reduced slightly as measured viscometrically and in the amylograph. A marked increase in flour gel firmness, measured on the Texturometer was evident with increasing chlorine treatment. Absorbance of the pigments extracted from the flour indicated chlorine exerted a bleaching action on the flour which was supported by a sensory panel's ranking of cake crumb color.

The performance of chlorinated and unchlorinated Triticale flour in a lean-formula cake made at four water levels was assessed by measurements of cake volume and crumb characteristics. Cakes made from chlorine treated flour were superior to those made from untreated flour in volume, subjective crumb score and in objective Texturometer evaluations of hardness, cohesiveness, gumminess and adhesiveness of the cake crumb. Increasing levels of chlorine, 0.2 to 0.6 ml/g flour, effected significant linear improvements in the subjective crumb score and in the Texturometer measurements of cohesiveness and adhesiveness over all water levels.

In all parameters of cake quality measured, increasing liquid levels in the cake batter caused a marked reduction in cake quality; although in the subjective crumb score, and in Texturometer measurements of crumb firmness, gumminess and adhesiveness the reduction in quality was moderated by chlorine treatment of the flour.

Improvements in cake texture due to chlorine were minimized at the lowest water level used, however a six-member sensory panel ranked cakes made from unchlorinated flour as gummier than cakes made from chlorine-treated flour and increasing chlorine tended to reduce crumb gumminess.

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INTRODUCTION

Advances in plant breeding and genetics over the past few decades have yielded a new cereal crop, Triticale, a cross-breed of rye and durum wheat. With continued improvements in Triticale's performance, this breeding program has advanced to the point at which one strain, Rosner, has been licensed for growth in Canada.

Both animal and human feeding trials have indicated that Triticale is equal or slightly superior to wheat in nutritive value. However, if Triticale is to have any utility as a human food, it must have desirable sensory qualities since food acceptance and selection are determined mainly on this basis.

Baking trials have indicated that Triticale does not perform well as a bread flour (Unrau and Jenkins, 1964), which, considering its rye and durum parentage is not surprising. Investigations of its use in quick breads have been limited to preliminary trials in these laboratories. Results indicated that improvements in the starch performance were required to eliminate the undesirable dense gummy texture which occurred.

Chlorine treatment of soft wheat and family flours is routinely practiced to improve their baking characteristics by effecting an increase in the swelling ability of the starch, thus increasing the viscosity and air-trapping ability of batters. The effects of chlorine treatment of cake flour are particularly noticeable, resulting in improvements in the grain, texture and volume of cakes (Parker and Harris, 1964).

For these reasons the present study was carried out to see if chlorine bleaching would improve the cake-baking performance of Triticale and so give it more promise for use in human foods.

REVIEW OF LITERATURE

Genetic and Agronomic Description of Triticale

Triticale is a hybrid cereal species produced by crossing durum wheat and rye. Its name was derived from a combination of the generic names of its two parents, *Triticum* and *Secale*. Triticale may be either hexaploid or octaploid, depending on whether it is produced from a cross of rye with a tetraploid or hexaploid wheat. The two types have been represented as follows (Chen and Bushuk, 1970):

T. turgidum + *Secale* = *Triticale* (hexaploid)
AABB + RR = AABBRR

T. aestivum + *Secale* = *Triticale* (octaploid)
AABBDD + RR = AABBDDRR

The Triticale breeding program of the Department of Plant Science, University of Manitoba, has been directed towards developing hexaploid varieties which appeared more fertile than octaploid Triticales (Larter *et al.*, 1968).

There is considerable interest in Triticale since its much larger head size offers a higher potential for yield than wheat grown under comparable conditions. Problems with sterility have resulted, to date, in failures to meet Triticale's yield potential; however work is under way to improve the new grain's fertility (Larter, 1968).

In May, 1969, the Rosner variety of Triticale was licensed for growing in Canada. This variety has been shown to outyield Manitou wheat by 4%, however it requires a slightly longer growing season than Manitou to reach maturity. Rosner was found to be fairly resistant to varieties of stem and leaf rust, but quite susceptible to ergot infection (Larter *et al.*, 1970).

Triticale appears to have considerable potential as a cereal crop with utility both as a livestock food and as a human cereal source. In limited commercial trials acceptable breakfast cereals have been produced, and favorable results have been obtained in the brewing and distilling industries (Larter *et al.*, 1968).

Nutritive Value of Triticale

In testing to date, Triticale appears to be equal or slightly superior to its parents in nutritive value. Trials with chickens indicated that the feed value of Triticale was approximately equal to hard spring wheat on a pound for pound basis as judged by growth, efficiency of feed utilization and ration metabolizable energy (Sell *et al.*, 1962). In trials with hogs and beef cattle, the feed efficiency of Triticale appeared equal or slightly superior to other grains such as barley and wheat, provided Triticale was not contaminated with ergot (Larter, personal communication).

In feeding trials with rats, Knipfel (1969) found that the protein quality of Triticale was equal to rye and superior to wheat.

Kies and Fox (1970) have investigated the nutritive value of Triticale (variety Rosner) protein for humans in a nitrogen balance study. From analysis of urinary nitrogen excretion of nine human adults fed two levels of protein, 4.0 or 6.0 g N per day, Triticale was shown to be slightly superior to the hard spring wheat tested.

In both of the above, and in the study with chickens (Sell et al., 1962) lysine was the most limiting amino acid in Triticale. The superiority of Triticale protein over wheat was, according to Knipfel (1969), due to a slightly higher content of lysine and sulfur amino acids in Triticale.

The protein content of Triticale flour was reported by Chen and Bushuk (1970) to be 9.8% (14% moisture basis) in contrast to much higher values reported earlier for hexaploid varieties (Unrau and Jenkins, 1964; Vaisey and Unrau, 1964). The gradual decline in protein level was presumably a result of breeding initiated to effect an improvement in other kernel characteristics (Larter et al., 1968). At 9.8%, the protein level in Triticale flour is lower than in hard spring wheats such as Manitou which contain around 13.6% protein (Chen and Bushuk, 1970).

When assessing the potential food value of Triticale for humans, it is important to consider, as well as nutritive value, its sensory qualities since food acceptance is determined mainly on this basis. Specifically, the color, flavor and texture of products made from Triticale must be desirable if the new cereal is to achieve food acceptance.

Investigations of the baking performance of Triticale have been limited to work by Unrau and Jenkins (1964) on its bread baking ability and to preliminary work in these laboratories on its performance in biscuits, muffins and pancakes.

Color of Baked Products Made from Triticale

A higher degree of crust browning observed in yeast breads made from Triticale was related by Vaisey and Unrau (1964) to the higher proportion of alcohol soluble sugars found in hexaploid Triticale. Durum and spring wheat flours contained from 11.4 to 18.5 mg soluble sugar per g of flour whereas hexaploid Triticales contained from 19.3 to 33.0 mg soluble sugar per g flour. In preliminary work, the crust color of Triticale pancakes was observed to be darker than the crust of a standard pastry flour pancake.

The crumb color of bread made with blends of Triticale, and Pembina wheat flour was darker than loaves made with either Pembina or Selkirk wheat flours (Unrau and Jenkins, 1964). This was related by the authors to the darker color of the flour as measured with the Kent-Jones colormeter. Similar observations were made in these laboratories with the crumb color of biscuits and muffins.

Flavor of Baked Products Made from Triticale

Triticale's unique flavor has been described in preliminary investigations as nutty, sweet and malty. In experiments with bread, the authors found Triticale's flavor appealing (Unrau and Jenkins, 1964). Sensory panels of from five to forty untrained judges liked the flavor of biscuits, pancakes and muffins made from Triticale as well as the flavor of the same products made from pastry or all-purpose flours. In all cases, the Triticale products were judged to have a stronger flavor which is likely due to the influence of its rye parent.

Texture of Baked Products Made from Triticale

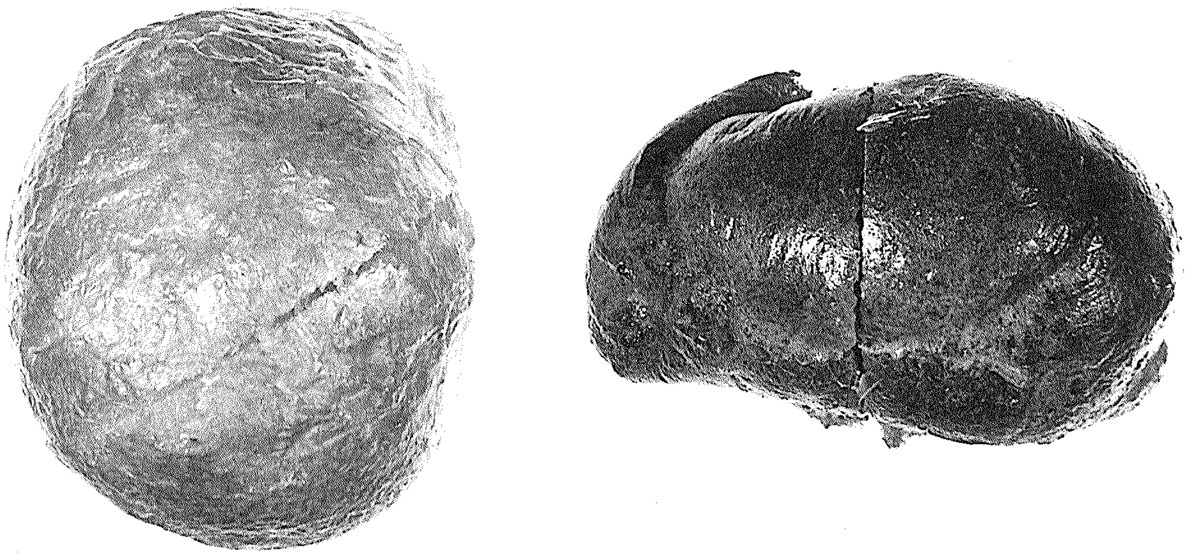
The texture of baked products is dependent on the functional properties of the various flour fractions. Unrau and Jenkins (1964) examined the bread baking characteristics of some hexaploid and octaploid Triticales. Although the flour protein content was high, ranging from 15.1 to 18.6% on a dry weight basis, the doughs tested in the farinograph were weak and had a short development time with the exception of one octaploid Triticale. Standard bread baking trials using hexaploid Triticale yielded loaves inferior in volume to a bread wheat. Although bread crumb characteristics were not described, lower volume would result in a loaf with a more dense, coarse crumb structure. However it was noted that satisfactory bread volume could be maintained when up to 40% Triticale flour was blended with a strong wheat flour.

Exploratory work in these laboratories compared the biscuit baking characteristics of Triticale with all-purpose and pastry flours. The texture of biscuits made from Triticale flour alone was soggy and gummy. However, when a 70:30 blend of Triticale with all-purpose flour was used, the biscuits were judged by a five-member untrained sensory panel to be equal in moistness and tenderness to those made from all-purpose and pastry flours.

Contrary to the results of Unrau and Jenkins (1964) with bread, the volume of the biscuits made from the Triticale-wheat flour blend was significantly less than the all-purpose flour biscuits. Also, the Triticale biscuits tended to spread more during baking than biscuits from all-purpose flour. The smaller volume and wider spread were presumably a reflection of the weaker gluten developed from Triticale flour.

In these same studies, when gluten was washed from flour-water doughs, a smaller amount of Triticale gluten was recovered, and it was more runny and sticky than all-purpose flour gluten. Baked gluten from both Triticale and all-purpose flours are shown in Figure 1.

Chen and Bushuk (1970) investigated the proteins of hexaploid Triticale, its parent rye and durum species, and



All-purpose flour

Triticale flour

Figure 1. Baked gluten extracted from one hundred grams of Triticale and all-purpose flour.

a hard red spring wheat. When the endosperm proteins were fractionated according to their solubility characteristics, Triticale was found to contain amounts intermediate between its parent species in all except the residual fraction (Figure 2). The authors concluded that the functional properties of Triticale were also likely to fall between those of rye and durum. Since neither parent possesses good bread baking quality, this would account for Triticale's poor performance in bread baking trials.

The major differences in the solubility patterns which likely contributed to the superior bread baking quality of the hard spring wheat tested were the lower proportion of water soluble proteins and the higher proportion of insoluble or gluten forming proteins.

Textural disadvantages have been apparent in batter-type quick breads as well as in biscuits and yeast breads made from Triticale. Since these quick breads are less dependent than bread or biscuits on the gluten characteristics of the flour for their structure, it is evident that the performance of other flour fractions in Triticale offer disadvantages for its use.

In preliminary work, pancakes made from Triticale flour were judged by a five-member, untrained sensory panel to be more moist and gummy than pastry flour pancakes. Muffins made from Triticale, all-purpose and pastry flours

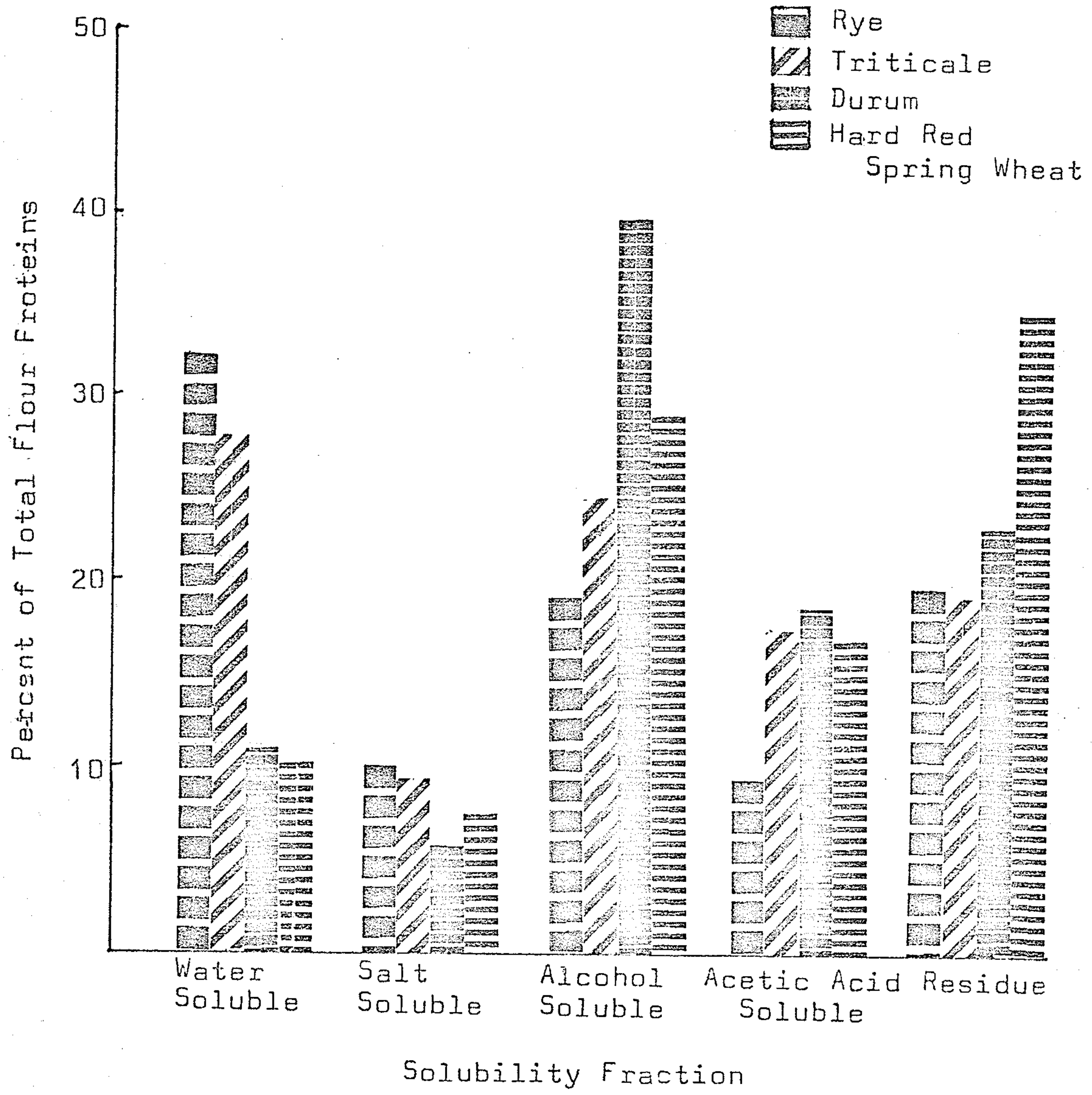


Figure 2. Distribution of endosperm proteins in the five solubility fractions for four grain species (Chen and Bushuk, 1970).

were liked equally by a panel of forty untrained judges; however comments from the judges indicated that the texture of Triticale muffins was soggy or gummy and needed improvement.

Gumminess, or the "denseness that persists through mastication" (Szczesniak _et_ _al_., 1963) which occurs in baked products made from Triticale must be considered as a sensory disadvantage. The consumer has been shown to be highly aware of food texture, and products which he finds difficult to manipulate in his mouth are not likely to be included in his diet (Szczesniak, 1969).

Gumminess, a recognized problem in baked products, has been investigated in cakes. In its extreme, gumminess has been recognized as dense, gelatinous layers which tend to form in mix-type cakes made at elevated liquid levels (Miller _et_ _al_., 1967). These layers were described as more moist, more fully gelatinized, and more dense than the normal cake crumb. It appeared that on standing, and during the initial stages of baking, separation of the batter emulsion occurred, with the batter fluid settling and the entrapped air escaping to the surface. The highly gelatinized, dense gummy layers formed as a result of the fluid separation.

Gumminess is associated with poor volume in cakes because the batters which have a tendency to form dense, gelatinous layers are very fluid, and thus have poor air trapping ability.

In a normal cake, the cellular structure is established during mixing by producing a foam of air in the aqueous phase of the batter. A stable crumb structure is achieved during baking as the starch gelatinizes and absorbs the free liquid in the batter (Howard et al., 1968). The resultant cake crumb is composed of air cells surrounded by cell walls of partially gelatinized starch granules embedded in a matrix of coagulated proteins (Griswold, 1962).

Achievement of a stable batter emulsion and a good final cake texture is dependent on a number of factors including the cake formula, method of combining ingredients, and the actual ingredients used. Of concern in the present study was the effect of the flour on cake structure.

Effect of Flour Proteins on Cake Texture

Flour proteins, which are found mainly in the gluten and water soluble fractions, are important in the aeration of cake batters and as determinants of the final crumb structure. Both the quantity and quality of the protein affect cake quality, with flours containing low levels of weak protein producing the best texture.

In studies involving cake-baking trials with fractionated reconstituted flour blends, Baldi et al. (1965) demonstrated that a minimum amount of protein was required to contribute sufficient cohesiveness to the batter ingredients to prevent incorporated gas cells from coalescing and escaping from the batter. However, once the batter was sufficiently cohesive to retain incorporated air, no further benefit was derived from additional protein in the flour, since the excessively cohesive nature of the batter discouraged the initial incorporation of air. Thus, although cake volume and texture improve with added protein, the effect is not linear, with high levels of protein having a detrimental effect.

In a similar study, Donelson and Wilson (1960b) showed that flours containing gluten which was weaker, or more readily solubilized produced cakes with better internal structure and larger volume than flours having stronger, excessively cohesive gluten.

Effect of Starch on Cake Texture

Granular starch has been shown to be critical in the formation of a typical cake structure (Howard *et al.*, 1968). Substitution of a non-granular amylose/amylopectin mixture for part or all of the granular starch in a high-ratio starch layer cake formula resulted in a cake which collapsed on cooling to form a sunken gel-like structure. Granular starch used alone in the starch layer cake formula produced an acceptable cake. The authors concluded that the starch granule was important in the thermal setting stage of baking, where it absorbed the free liquid in the fluid batter to form the stable cellular structure of the baked cake.

Gelatinization properties of granular starch, that is the temperature range over which gelatinization occurs, and the viscosity of the gelatinized starch, have been shown to influence layer cake structure (Miller and Trimbo, 1965; Howard *et al.*, 1968). Cakes made with rice or pineapple starches which have high gelatinization temperatures, 61-78°C and 85-90°C respectively, did not achieve a stable structure during baking, and on cooling collapsed completely (Howard *et al.*, 1968). Examination of the starch in the baked cakes showed that the granules were only slightly swollen and highly birefringent at the end of the baking period. Cakes made with wheat starch which gelatinizes at a much lower temperature (52-63°C) set during baking to form a normal crumb structure.

Miller and Trimbo (1965) have also demonstrated a relationship between the initial gelatinization temperature of starch and white layer cake quality. Of the four flours they tested, those that gelatinized at a higher temperature were more susceptible to forming cakes with sunken or dipped top contours when the liquid level in the cake formula was reduced to 80% of the optimum level. Steps taken to lower the gelatinization temperature of the starch such as the addition of more water, reduction of the sucrose level in the batter or the addition of chemicals such as urea or sodium salicylate, resulted in a higher consistency of the cake batter at a lower temperature, and eliminated the tendency of the flour to form dipped cakes.

It is apparent that starches which gelatinize at a relatively low temperature to give an early, high consistency impart stability to the fluid batter emulsion, and hence yield a desirable crumb structure.

Examination of the pasting characteristics of starches extracted from Triticale and its rye and durum parents revealed that Triticale resembled its rye parent in that it had a low maximum viscosity which it achieved at a low temperature (Figure 3) (Hill, 1969).

Extensive starch damage was eliminated as a cause for the low peak viscosity since wet milling the grain to eliminate starch damage caused no improvements in the pasting characteristics of either Triticale or rye. Also, microscopic examination of the starch granules confirmed a low degree of starch damage in Triticale and rye.

The poor pasting characteristics were shown to be due to high alpha-amylase activity since a marked improvement in the viscosity characteristics of both rye and Triticale occurred when the starches were treated with silver nitrate to deactivate the enzyme (Figure 4).

High levels of alpha-amylase activity in flour have

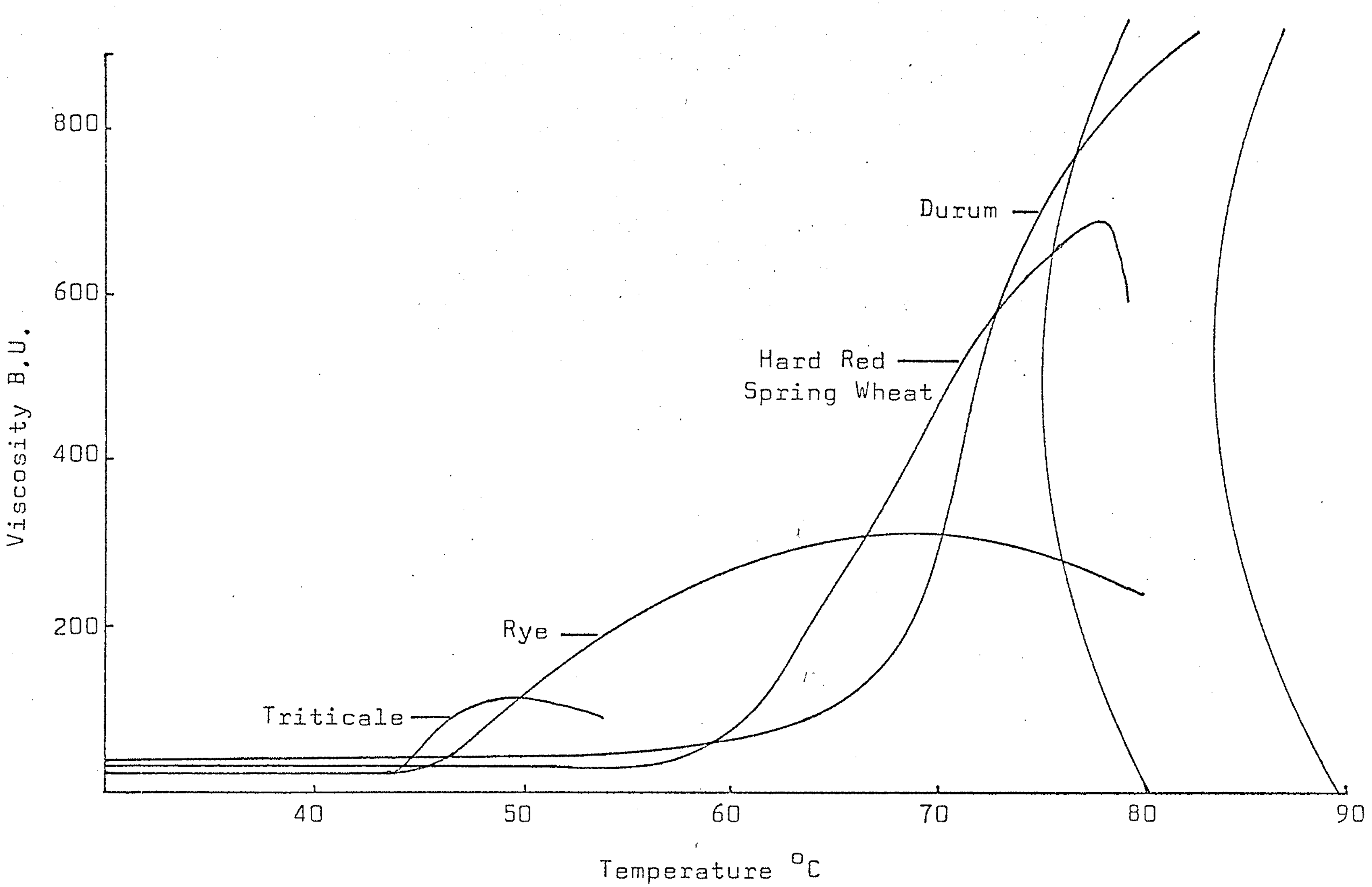


Figure 3. Amylograph curves for 10% starch suspensions of Triticale, its parents and a hard red spring wheat (Hill, 1969).

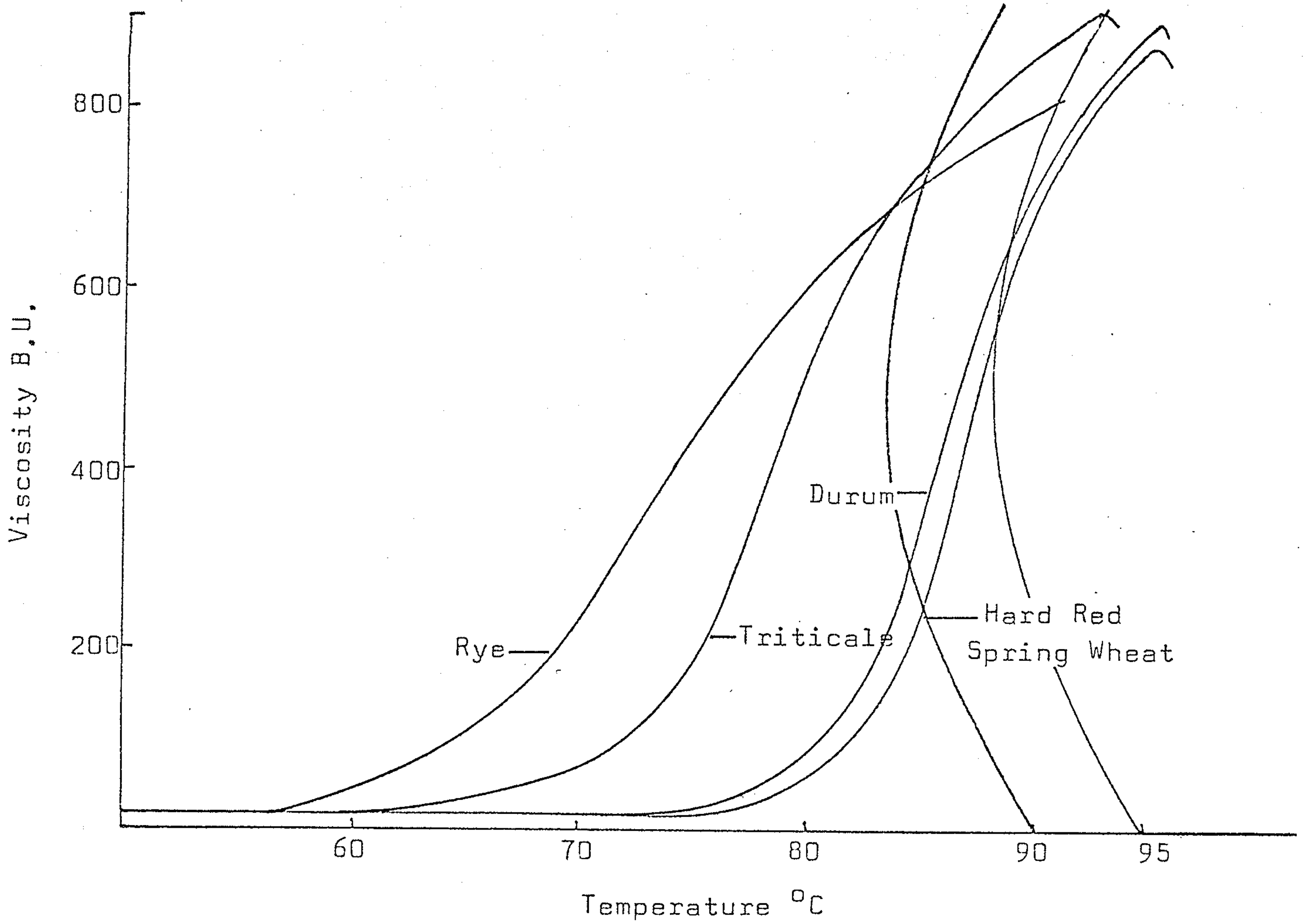


Figure 4. Amylograph curves for silver nitrate treated starch suspensions of Triticale, its parents and a hard red spring wheat (Hill, 1969).

been associated with the occurrence of gumminess or stickiness in the crumb of baked products. This enzyme cleaves the 1,4 glucosyl linkages of the starch polymers in damaged or gelatinized starch granules, eventually resulting in the complete destruction of the granule (Sandstedt, 1955). The remaining intact starch granules are less able to absorb the free liquid in the batter or dough during the latter stages of baking, and the resultant crumb is sticky or gummy.

Gumminess in cakes has also been associated with the use of unimproved flour (Wilson and Donelson, 1965; Miller _et al._, 1967). These authors noted that cakes made from unimproved flour appeared to rise normally during baking; however on cooling they collapsed completely, yielding a coarse soggy structure with a sunken top contour. Observations of mix-cakes made from unimproved flour in a special glass pan revealed that during baking separation of the batter emulsion occurred, with a dense gummy layer forming on the bottom of the pan, and a band of large air cells on the top. It was this weak band of air cells which collapsed during cooling to give the cake a sunken appearance. The use of cake flour treated with chlorine, to the optimum level for cake baking, prevented separation of the batter emulsion and formation of gummy layers (Miller _et al._, 1967) and yielded cakes with a more normal rounded top contour, a fine uniform crumb and increased layer volume (Wilson and Donelson, 1965).

The fractions in the chlorine treated flour responsible for improvements in cake structure and increase in volume were shown by Sollars (1958b) to be the prime starch and gluten, with the effect of the chlorinated prime starch predominating.

Effect of Chlorination on Starch Properties

In work done by Whistler and Pyler (1968), the major action of chlorine on wheat starch appeared to be oxidative depolymerization of the polysaccharide at the glucosidic bond. One of the earlier uses made of this reaction was in the production of thin boiling starches, or starches which have a reduced ability to swell in hot water. It was noticed later, that with controlled application of chlorine, the swelling capacity of the starch was enhanced initially before it was reduced (Alexander, 1939). Presumably during the initial stages of depolymerization the dense crystalline structure of the starch granule is disrupted so that swelling may occur more easily than in the untreated granule. However, with excessive depolymerization, the granule structure is weakened and its swelling powers are greatly reduced.

These observations have been supported, in part, by recent observations (Kulp et al., 1969). Starches extracted from flours treated with increments of chlorine up to the optimum level for cake baking performance were similar to untreated starch in their hot and cold paste consistencies and swelling power. If higher chlorine treatments were used, the paste consistency was drastically lowered due to oxidative depolymerization of the starch polymers.

In the same study it was found that the solubility and water binding capacity of the starch increased with increasing chlorine treatment of the flour (1.0 to 16.0 oz. per cwt.).

Chlorine may also affect the swelling ability of starch and hence its solubility indirectly through its action on flour lipids (Youngquist _et_ _al_., 1969). The natural starch granule has a lipid coating, and when it is gelatinized in a sugar solution such as one would find in a cake batter, the lipid complexes with the starch, inhibiting swelling and the release of soluble starch. With less soluble starch released, gel formation would be weakened, and cake setting retarded. The authors hypothesized that on chlorination the unsaturated lipids were rearranged so that they were unable to complex with the starch due to their steric nature; thus starch swelling was not inhibited and the gelation properties of the flour were improved.

In addition to improvements in starch performance through the action of chlorine on the starch and lipids, amylograms of flour have indicated an increase in paste viscosity due to a decrease in amylolytic power with increasing chlorine treatment (Kulp _et_ _al_., 1969).

Effect of Chlorination on Flour Proteins

In an attempt to fractionate bleached flour by water extraction, Sollars (1958a) noted that up to 40% of the flour proteins were found in the water soluble fraction. An increase in the level of soluble proteins with increasing chlorine treatment of flour was also noted by Kissel (1969), and was related, in part, to an increase in layer cake volume in baking trials.

The improving effect of bleached gluten on the cake baking quality of flour must be due to the increased proportion of soluble proteins which have been shown to be important in the aeration of cake batters (Howard *et al.*, 1968).

Experimental Hypothesis

It is likely that the gumminess encountered in previous baking trials with Triticale was due both to the high alpha-amylase activity in the flour and to the use of unimproved flour. In the present study the possibility has been investigated that treatment of Triticale flour with chlorine gas would improve its cake baking performance through improvements in starch and protein performance. Specifically, because of chlorine's action on flour lipids and starch, an improvement should be observed in the starch swelling and gelation properties, and by a reduction in amylolytic activity with chlorine treatment an increase in the viscosity of the gelatinized starch should be evident.

The above effects, along with the increased solubility of the flour proteins with chlorine treatment should result in some improvement in cake volume and reduction in crumb gumminess.

Since a creamy white color is desirable in baked products, the bleaching action of chlorine gas on flour pigments should improve the crumb color of cakes made from Triticale, further enhancing their sensory qualities.

METHODS

In examining the effect of chlorine gas on the cake baking quality of Triticale, pertinent physical and chemical properties of the flour were measured as well as its liquid tolerance and baking quality.

Flour Preparation

Triticale flour was milled in a Buhler laboratory mill from the 1968 crop (variety Rosner). After three months of storage at 6°C, the flour was bleached[1] at five rates, 0.2, 0.3, 0.4, 0.5 and 0.6 ml chlorine per g of flour, in a McClellan blender with a five pound capacity. The chlorine gas was introduced into the blender by gravity water displacement and the blender was tumbled for twenty minutes during each gas application. Since only 1000 ml of gas could be introduced into the blender at one time, it was necessary to make successive application for the heavier chlorine treatments. One portion of flour was left unbleached and served as a control sample.

Measurements of Flour Quality

The pH of triplicate samples of each flour treatment was determined electrometrically using a Corning Scientific

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[1] Courtesy of General Mills Research Laboratories.

Instrument pH meter, Model 5(AACC, 1962).

Alpha-amylase activity of 0.5 g samples of each flour was measured in duplicate using a viscometric method (Tipples, 1969). The high enzyme activity in the flour necessitated the use of 200 ml of extracting solution.

The pasting characteristics of single samples of the six flour treatments were followed in the visco-amylograph using AACC(1962) Method 22-10.

The gel strength of the six flour treatments was assessed in triplicate by measuring hardness on the General Foods Brabender Texturometer of flour gels made from 150 g flour and 350 ml water. The flour and water were stirred together to make a paste, then boiled for two minutes, stirring vigorously. The cooked paste was poured into three enamelled tin containers 6.5 cm in diameter and 1.5 cm deep with a masking tape collar so that the containers were overfilled. The samples were held 17 hours at 6°C before they were tested on the Texturometer.

For testing, the masking tape collar was removed, and the excess sample cut off. The gels in the tin containers were then clipped to the aluminum platform of the Texturometer and tested under the following conditions.

Volts	0.5 to 1.5
Chart speed	750 mm/min
Plunger	nickel, 50 mm diameter

Sample cup	aluminum plate
Clearance	6.5 mm
Chewing speed	low

The color of single samples of the flour treatments was estimated by measuring, in triplicate, the absorbance of the pigments extracted from the flour in water saturated n-butanol on a Unicam SP.600 spectrophotometer (AOAC, 1965).

Baking Trial

Baking quality and liquid tolerance of the six chlorine treatments of Triticale flour were assessed by volume and crumb evaluations of cakes made by a modification of Kissel's (1959) lean formula cake recipe as shown in Table I. The lean formula cake was chosen since it has been shown to be sensitive to flour quality, bleaching treatment and water levels (Donelson and Wilson, 1960a; Wilson and Donelson, 1965).

Four replications of the baking trial were performed in which six chlorine treatments and four water levels were examined in a factorial arrangement as shown in Table II. Testing the effects of chlorine level on Triticale flour in cakes made at several water levels had a two-fold advantage. First it served to make obvious differences due to chlorine that were less noticeable at the lowest water level. The second advantage of using several water levels was to see if chlorine would enhance liquid tolerance of Triticale as it

TABLE I

LEAN-FORMULA CAKE RECIPE

Ingredients	Quantity[1]	Composition (% flour basis)
Flour	150 g	100
Sugar, granulated	195 g	130
Shortening, high-ratio[2]	41.8 g	27.9
Baking powder, double action[3]	7.1 g	4.7
Water, distilled	135-189 ml	90-126

[1] Recipe yielded 2 - 6" layers.

[2] Crisco, Procter and Gamble Co.

[3] Calumet, General Foods Ltd.

TABLE II

TREATMENT DESIGNATIONS IN THE BAKING TRIAL

Water level in cake formula (% flour basis)	Chlorine treatment of flour (ml Cl /g flour)					
	0	0.2	0.3	0.4	0.5	0.6
90	C_0 W_1	C_2 W_1	C_3 W_1	C_4 W_1	C_5 W_1	C_6 W_1
102	C_0 W_2	C_2 W_2	C_3 W_2	C_4 W_2	C_5 W_2	C_6 W_2
114	C_0 W_3	C_2 W_3	C_3 W_3	C_4 W_3	C_5 W_3	C_6 W_3
126	C_0 W_4	C_2 W_4	C_3 W_4	C_4 W_4	C_5 W_4	C_6 W_4

is reported to with other flours (Wilson and Donelson, 1965).

Shortening, baking powder and sugar for the entire baking trial were each obtained in one lot. The flour and shortening were stored at 6°C during the experiment.

The mixing method was adjusted from using a concentrated sugar solution, as described by Kissel (1959), to using granulated sugar as shown in Table III. This simplified operations by eliminating the time required to make up and check the concentration of the sugar solution. Preliminary trials with this method indicated that the cakes appeared comparable to those produced using the solution method.

To facilitate comparisons among cakes over water levels, the weight of batter scaled was adjusted according to the liquid level in the batter as shown in Table IV, so that each cake contained the same weight of dry ingredients (Wilson and Donelson, 1965).

Baking was done in a rotary hearth test baking oven[2] at 190°C (375°F). As shown in Table IV, the baking times were increased with increasing water levels so that the cakes were done to a constant crust color as judged by eye.

Cakes were cooled on wire racks ten minutes prior to

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[2] National Manufacturing Co., Lincoln, Nebraska.

TABLE III

MIXING SCHEDULE FOR LEAN-FORMULA CAKE

Action	Ingredient
Blend by sifting 3 X	Flour, sugar and baking powder
Cut into dry ingredients	Shortening
Add	90 ml water
Mix 0.5 min at low speed.[1] Scrape down. Mix 2.5 min at medium speed. Scrape down. Mix 0.5 min at medium speed. Scrape down.	
Add	Remainder of water in formula
Mix 0.5 min at low speed. Scrape down. Mix 1.5 min at medium speed. Scrape down.	
Scale into 2 - 6 inch layer pans	
Bake in oven at 190°C	

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[1] A Kitchen Aid Model 4-C mixer was used. Speed 1 corresponds to low speed and speed 2 to medium.

TABLE IV

SCALING WEIGHTS AND BAKING TIMES FOR THE LEAN-FORMULA CAKE MADE WITH INCREASING LIQUID LEVELS

Liquid (% flour basis)	Scaling weight per layer (g)	Baking time (min)
90	231.66	21
102	239.54	23
114	247.43	25
126	255.31	27

removal from pans. After an additional fifty minutes cooling, one of the two cakes from each baking lot was bisected for subjective crumb evaluation and cross-sectional tracing. The two cakes from each test batter were then wrapped together in a polyvinyl chloride film and held at $-15^{\circ}C$ for two months.

Volume, as estimated by rape seed displacement, was measured on the frozen wrapped cakes. This afforded an increase in test precision since there was less danger of the rape seeds compressing the frozen cakes. Also, because the cakes were wrapped during testing, they were not soiled and could be used later in sensory evaluations.

Unavailability of the Texturometer during the baking trial necessitated holding the cakes for two months in frozen storage until this test could be performed.

Measurements of Cake Quality

Volume of the cakes was estimated by two methods. For the first estimate, one cake from each test batter was bisected vertically and the area of its cross-sectional tracing was measured using a compensating polar planimeter. The results were expressed as the cross-sectional area per layer, in square centimeters.

Second, the volume of the two frozen, wrapped cakes from each test batter was measured by rape seed displacement in a 10 x 10 inch National Loaf Volumeter. This reading was expressed as the average volume per layer in milliliters for the two layers from one recipe. To determine the relationship between the two cake volume estimates, a correlation coefficient was calculated (Snedecor and Cochran, 1967).

The crumb characteristics of the cake cross-sections were evaluated one hour after baking by the experimenter using the following eight point scale:

1 = Gummy layer more than 1 cm thick
2 = Gummy layer between 0.5 and 1 cm thick
3 = Gummy layer less than 0.5 cm thick
4 = Soggy uneven crumb with trace gummy layer
5 = Coarse uneven crumb
6 = Fine uneven or coarse even crumb
7 = Excessively fine crumb
8 = Fine even crumb.

A physical evaluation of the crumb characteristics was made using the Texturometer. The testing was carried out on the frozen cakes after thawing for twelve to sixteen hours. Four test samples, with dimensions 1¼ x 1¼ x ½ inch, were taken from the center of each cake as shown in Figure 5. The top and bottom crusts of the cake were removed for testing except for some cakes made at the highest water level, whose height allowed for removal of only the top crust. All sampling was done in a stainless steel cutting box.

Cakes from three replicates were tested. Recorder

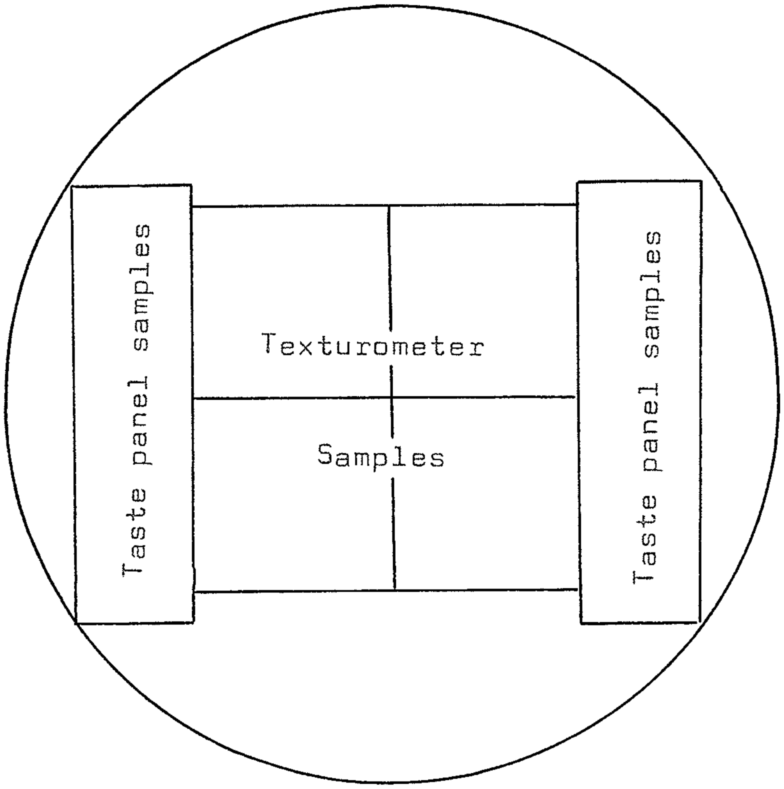


Figure 5. Sampling design of cakes for Texturometer and sensory trial.

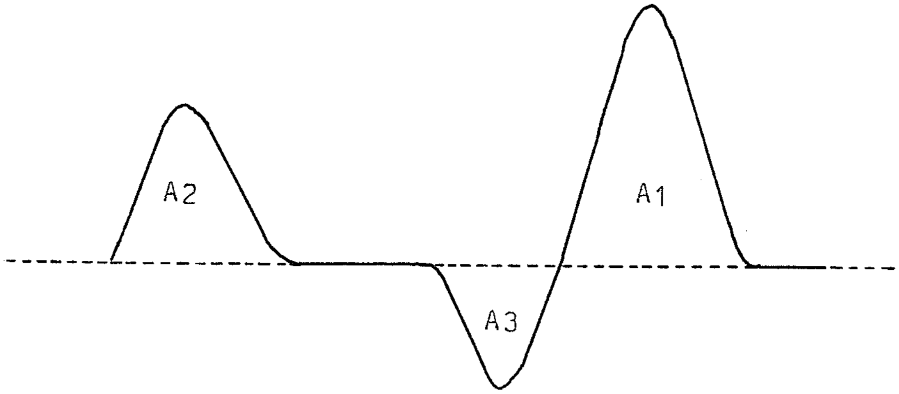
pen skipping spoiled the results from occasional samples from some treatments, so to achieve a uniform number of sample values within each treatment, one or two values were discarded at random from those treatments having more than six sample values.

Incorrect sampling procedures necessitated eliminating the results for treatment C_6 W_1 in the third replicate. Data for this treatment was estimated by a missing plot technique (Snedecor and Cochran, 1967) except in the case of the adhesiveness parameter where this estimation yielded a negative value. Since negative values for adhesiveness are not instrumentally possible, the missing values were assumed to be zero, and analysis was carried out as if no values were missing.

The test conditions were as follows:

Volts	1
Chart speed	750 mm/min
Plunger	nickel, 50 mm diameter
Sample cup	aluminum plate
Clearance	6.5 mm
Chewing speed	low

The parameters of hardness, cohesiveness, gumminess and adhesiveness were determined for each sample as shown in Figure 6. The areas A1 and A2 were estimated by cutting out the peaks, weighing them on an analytical balance, and



Hardness = $\frac{\text{Height of A1 (cm)}}{\text{voltage input}}$

Cohesiveness = $\frac{\text{Area of A2}}{\text{Area of A1}}$

Gumminess = Hardness x Cohesiveness

Adhesiveness = Height A3 (cm)

Figure 6. Analysis of textural parameters from a typical texturometer curve.

transforming the weights, by multiplying with an appropriate factor, into square centimeters. Because of the small size of A3, adhesiveness was estimated by the height, rather than the area of that peak.

To substantiate further the effect of chlorine on the cake crumb, a highly experienced panel of six judges was asked to rank the cakes from the lowest water level (W) for gumminess and color. Two replicates of cakes were ranked for gumminess and four for color.

Gumminess was defined for the judges as "the denseness that persists throughout mastication; the energy required to disintegrate a semi-solid food to a state ready for swallowing" (Szczesniak, 1963). Panelists were asked to assign a value of one to the most, and six to the least gummy sample. Gumminess rankings were carried out in individual booths. Red lighting was used since in a preliminary trial it was found that the judges were allowing the color of the cake sample to influence their gumminess rankings.

Color rankings were carried out in a MacBeth light booth under a standard daylight source. Panelists were asked to assign a value of one to the most yellow and six to the least yellow sample.

Analysis of variance was applied to the experimental results from the baking trial (Snedecor and Cochran, 1967). The ranked data from the sensory trial was transformed into scores according to Fisher and Yates (1957) before performing analysis of variance.

RESULTS AND DISCUSSION

Measurements of Flour Quality

The physical and chemical measurements of quality of the six chlorine treatments of Triticale flour generally were indicative of improvements in flour quality with increasing chlorine treatment (Table V). The gradual decline observed in flour pH with increasing chlorine treatment was expected since flour pH is frequently used to monitor level of chlorine application. As flour pH's from 4.6 to 5.1 have been suggested as optimum for layer cakes or high-ratio cakes (Pratt, 1964), it was possible that the highest chlorine treatment (C_6) with pH 4.98 was not at the level for optimum cake baking performance.

The viscometric measurement of alpha-amylase activity indicated a gradual decline in amylase activity in the flour with increasing chlorine treatment except for C_5 in which the amylase activity appeared to be slightly higher than all but the unchlorinated (C_0) flour. In the amylograph however, there was a consistent increase in the maximum viscosity of the pasted flour with increasing levels of chlorine treatment. Although the results in this experiment were not in strict agreement, both of these measurements are accepted as being indicative of amylase activity. Since the starch substrate in the viscometric method (Tipples, 1969) was

TABLE V

MEASUREMENTS OF FLOUR QUALITY OF SIX CHLORINE TREATMENTS OF TRITICALE FLOUR

Characteristic measured	Flour chlorine treatment					
	C_0	C_2	C_3	C_4	C_5	C_6
Flour pH[1]	6.25	5.82	5.62	5.39	5.15	4.98
Amylase activity Viscometric[2] (V.R.U./g-14% mb.)	10.61	9.95	9.91	9.72	10.03	8.63
Amylograph (Maximum viscosity B.U.)	130	150	160	175	180	200
Gel strength[1] (Texturometer hardness, cm/volt)	5.9	13.7	13.7	22.6	20.9	26.5
Flour color[1] (Carotene, ppm)	3.76	3.91	2.71	2.26	1.26	0.84

[1] Mean of triplicate determinations.

[2] Mean of duplicate determinations.

potato starch rather than Triticale starch, those results should be more independent than the amylograph technique of other changes in the chlorinated starch which are not directly associated with amylase activity. The divergent results for C_5 in the viscometric method are not easily explained, since the pH of that sample indicated it had received a higher chlorine treatment than C_2, C_3 or C_4, and the flour for C_5 was drawn from the same pool as the other samples.

Generally, the amylase determinations were in agreement with those of Kulp et al. (1969) who, using the amylograph technique, observed a decrease in amylase activity with increasing chlorine treatment. Yamazaki (1969) also reported higher amylograph viscosities at lower temperatures for chlorine treated flours; however he did not relate this directly to decreased amylase activity.

Since achievement of a higher batter viscosity at a lower temperature has been shown to be important in establishing a desirable cake structure (Miller and Trimbo, 1965; Howard et al., 1968), it is likely that some improvement in the cake baking properties of Triticale flour should be evident through the decreased amylase activity effected by chlorine treatment.

However, it must be noted that even at the highest rate of chlorine application the amylase activity was still relatively high. The lowest activity of 8.63 V.R.U./g flour (C_6) was comparable to that observed in germinated Selkirk wheat (Tipples, 1969) and the amylograph viscosity of C_6 was lower than viscosities found desirable in flour for home baking, breads (Pratt, 1964) or than viscosities of 714 to 938 B.U. commonly found in commercial soft wheat flours (Matthews, 1970).

Increasing chlorine treatment dramatically improved the gelation characteristics of Triticale flour as indicated by the four-fold increase in gel firmness measured on the Texturometer (Table V). Degradation of the starch polymers by acid or enzyme hydrolysis has been associated with reduced gel firmness. It was likely that the amylase activity in C_5 was higher than in the flours treated with chlorine at a lower rate, as was indicated by the viscometric measurement, and hence was responsible for the reduced firmness observed in that gel.

Starch gel strength has been related to the ability of the starch granules to swell and release soluble starch, mainly the linear polymer, which on cooling gels (Bean and Osman, 1959). The swelling ability of the starch depends, in turn, on the closeness of association of the starch polymers within the starch granule (Leach, 1965).

The increased gel firmness observed in chlorinated Triticale flour likely reflected an increase in swelling power of the starch granule which might have been brought about by oxidative depolymerization, by chlorine, of the starch polymers in the intact granule (Whistler and Pyler, 1968), loosening the strength of their association. The increased gel strength may also have been partially due to oxidative rearrangement of the flour lipids, limiting their depressing effect on starch swelling as hypothesized by Youngquist et al. (1969).

An improvement in the cake baking properties of chlorinated Triticale flour should be evident through its improved gelation characteristics as gelation of starch has been shown to be important in the final setting of the cake structure (Howard et al., 1968; Youngquist et al., 1969).

Chlorine treatment of Triticale flour exerted some bleaching action on the flour pigments as shown in Table V. The bleaching action of chlorine is well known; however chlorine's usage is mainly due to its effect as a flour improver. In practice, chemicals such as benzoyl peroxide are generally added to flour to exert a color removal function (Parker and Harris, 1964), and yield the creamy white color which appeals to the consumer.

Measurements of Cake Quality

Both measurements of cake volume, cross-sectional area and seed displacement indicated a significant linear decrease in volume with increasing water levels in the cake formula (Figures 7 and 8). The cross-sectional area measurement of volume indicated, in addition a quadratic effect of water level on cake volume, with less depression in volume resulting from increasing the water level from W_1 to W_2 than with further increases (Table VI and Figure 7).

Unbleached Triticale flour yielded, on the average, cakes significantly lower in volume than bleached flour (Table VI and Figures 9 and 10). A similar volume response to chlorination has been observed in lean-formula cakes by other workers (Kissel, 1959, 1969; Wilson and Donelson, 1965). Sollars (1958b) did not find a volume increase due to using chlorine treated flour in a full-formula, high-ratio white layer cake, but did see a marked volume increase in yellow layer cakes.

The relationship between level of chlorine-treatment and cake volume was quadratic in nature. At all water levels, maximum volume was achieved at the lowest level of chlorine treatment (C_2), and increasing chlorine treatment up to C_4 caused a slight depression in cake volume. The depressing effect levelled off at around C_4, at which point the volume appeared to show a slight increase again (Figures 9 and 10). Other workers have reported a marked increase in layer volume with increasing chlorine treatment of flour to a point at which the flour was overchlorinated, and the volume was depressed (Kissel, 1959, 1969; Wilson and Donelson,

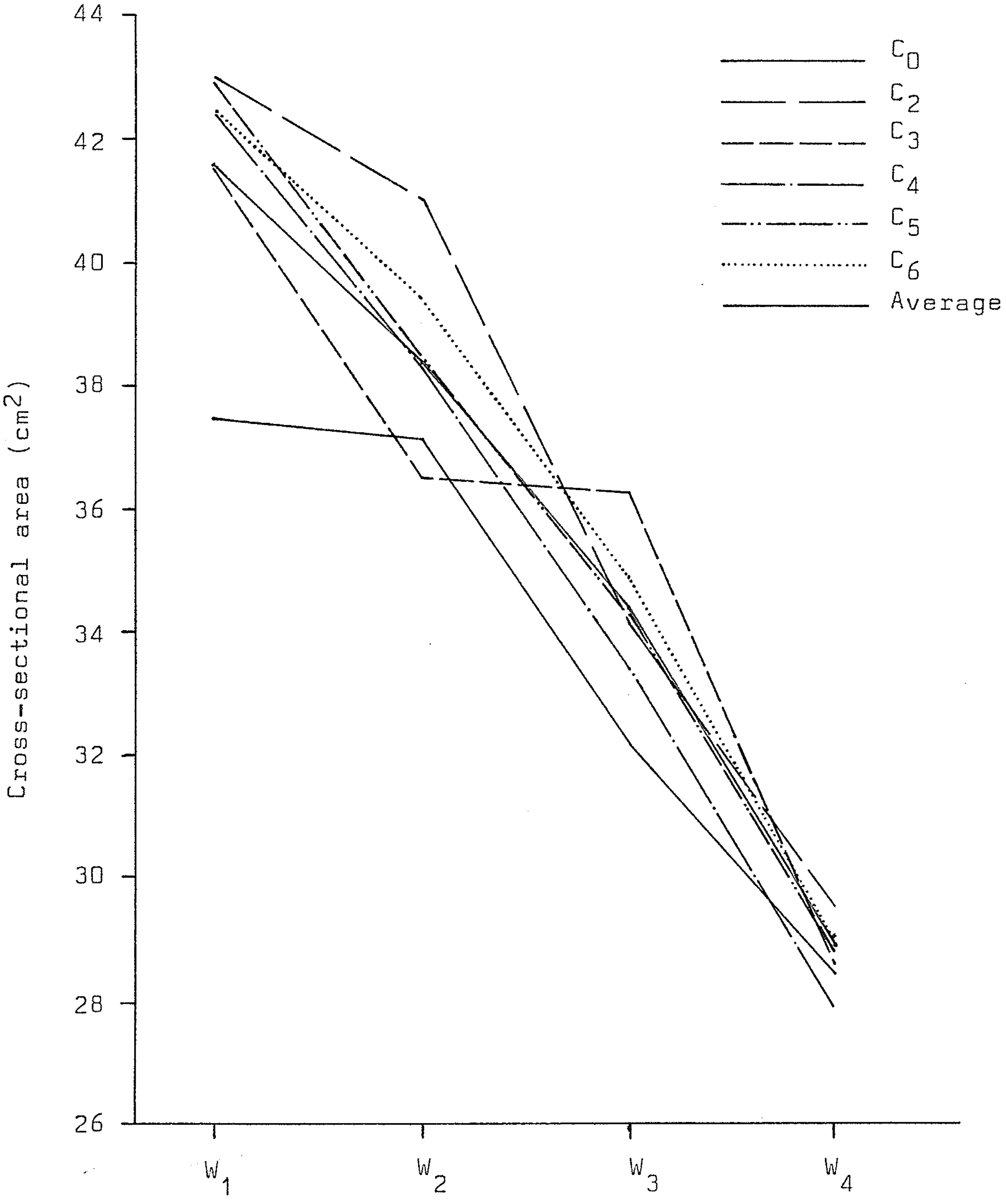


Figure 7. The effect of water level in the batter on cake volume estimated by cross-sectional area.

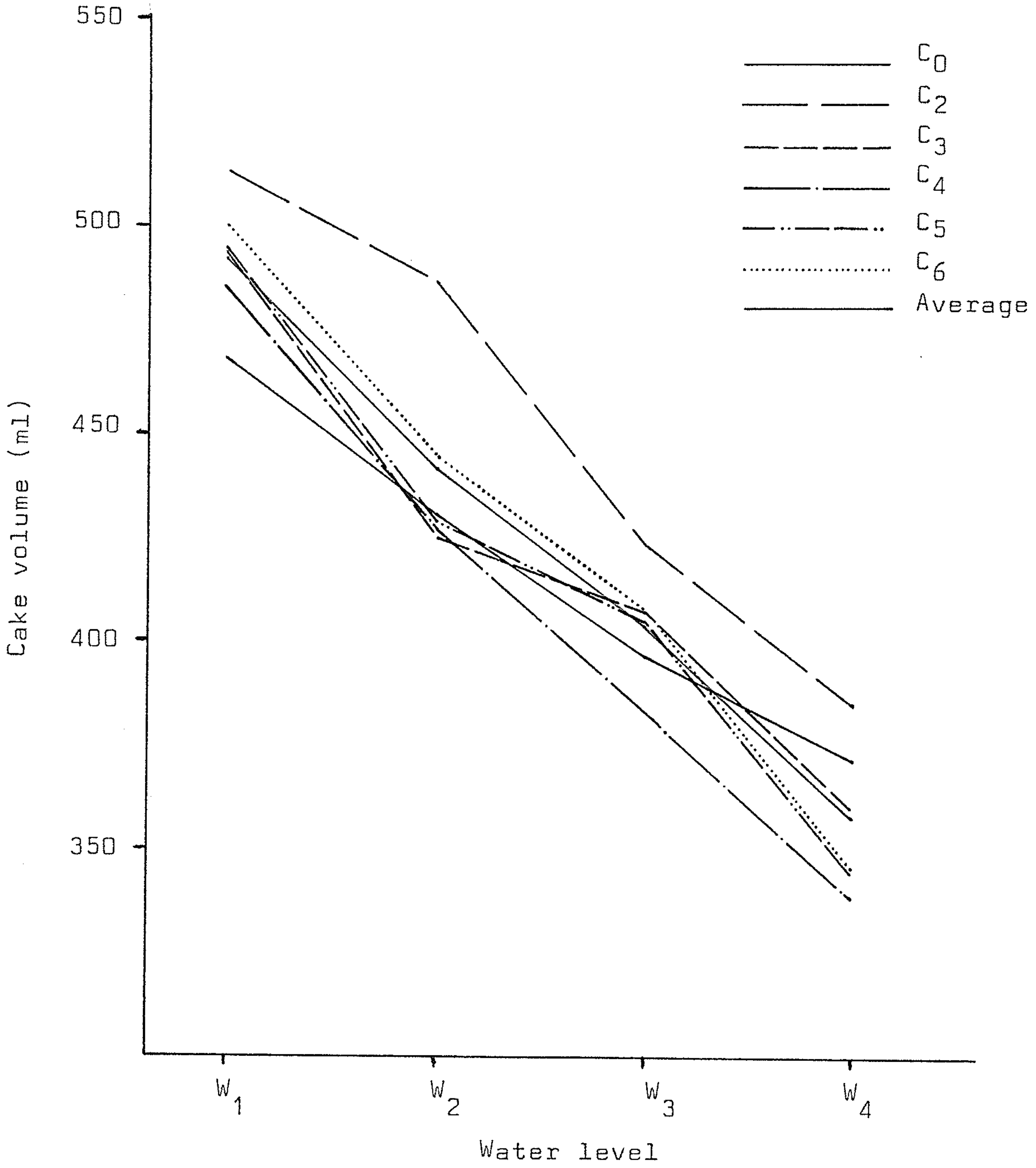


Figure 8. The effect of water level in the batter on cake volume measured by seed displacement.

TABLE VI

ANALYSIS OF VARIANCE OF CAKE VOLUME AND SUBJECTIVE CRUMB SCORE

Source	df	Volume Mean Square		Crumb Score Mean Square
		Cross-sectional area (cm^2)	Seed displacement (ml)	
Water	3	750.5**	76,330**	46.4**
W_{linear}	1	2220.1**	227,941**	131.3**
$W_{quadratic}$	1	31.4**	319	7.6**
W_{cubic}	1	0	737	0.3
Chlorine	5	19.0**	3,464**	17.2**
C_0 vs rest	1	74.0**	1,080*	43.8**
C_{linear}	1	0.4	5,464**	39.0**
$C_{quadratic}$	1	17.8*	9,978**	2.0
C_{cubic}	1	2.5	733	0.1
$C_{residual}$	1	0.3	64	1.1
Water x Chlorine	15	5.9	534*	0.4
Blocks	3	10.1	4,567**	0.7
Error	69	4.2	253	0.7

**Significant $P < 0.01$.

*Significant $P < 0.05$.

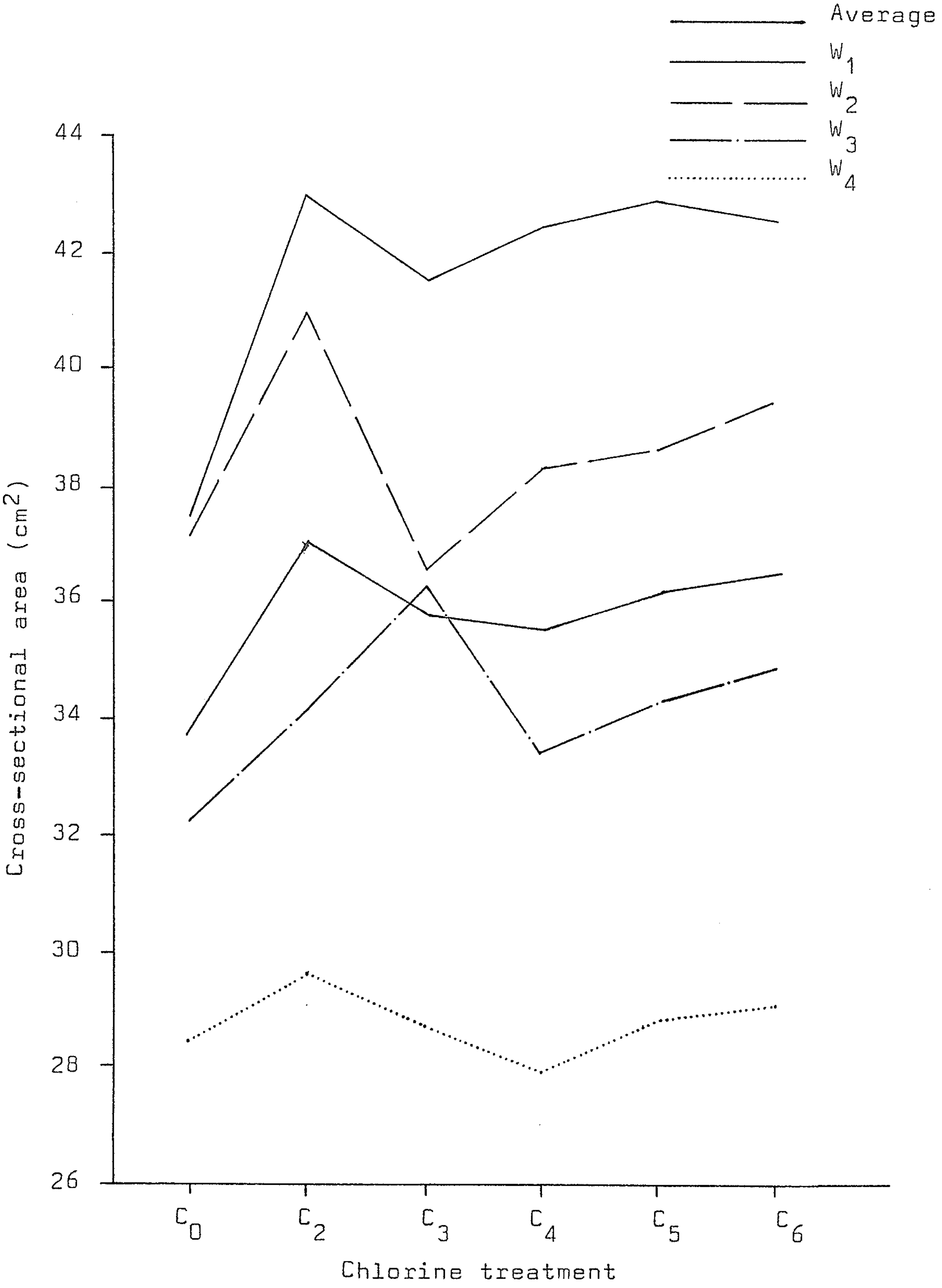


Figure 9. The effect of chlorine on cake volume estimated by cross-sectional area.

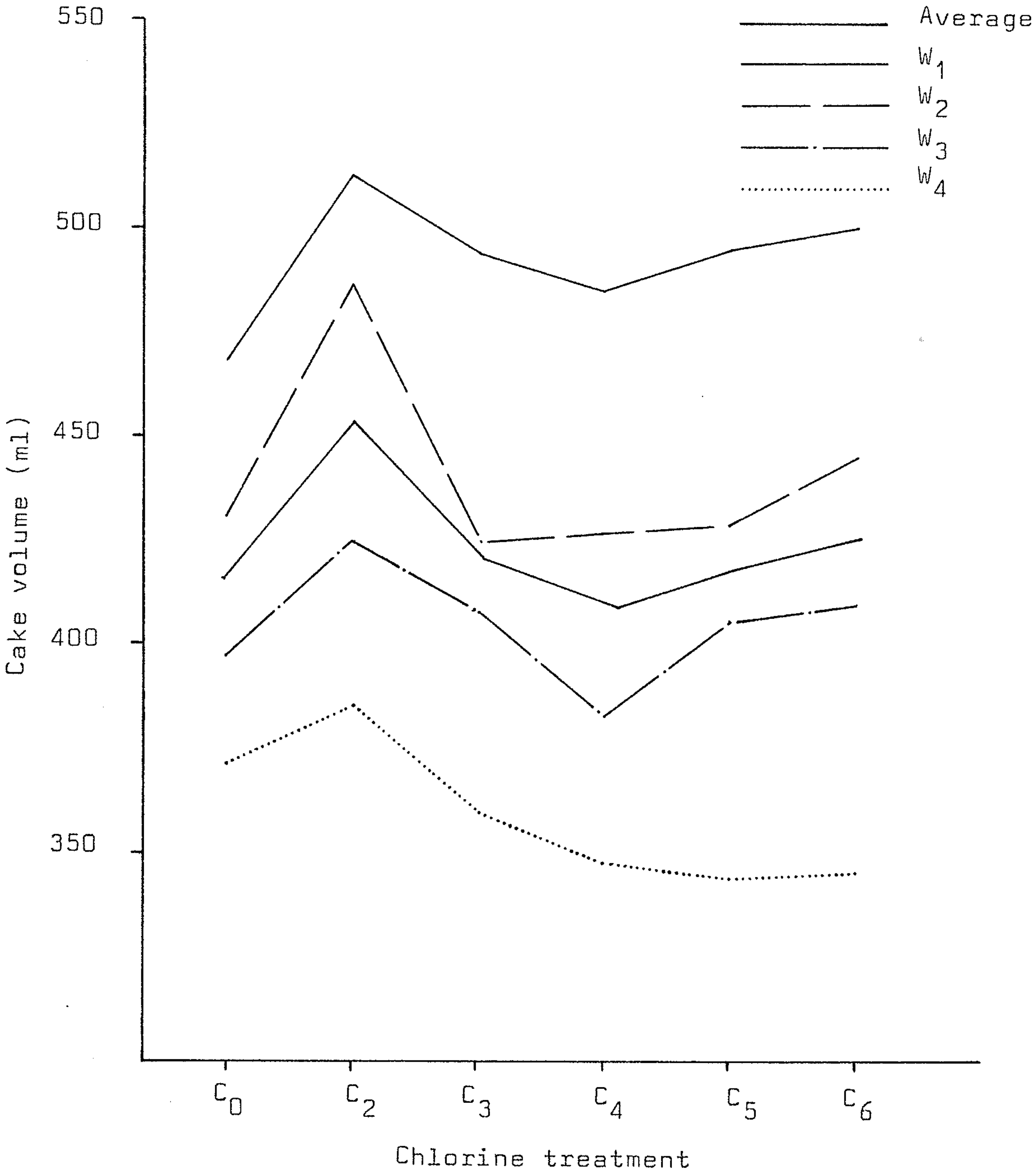


Figure 10. The effect of chlorine on cake volume measured by seed displacement.

1965). The failure of this experiment to show any net improving effect of increasing chlorine treatment on cake volume may have been due to the fact that the lowest pH achieved was 4.98, and the optimum pH for cake baking has been shown, by the above authors, to be around pH 4.6 to 4.8, depending on the flour.

The reason for the quadratic and a slight linear depression of volume which was effected by increasing chlorine treatment was not clear, as individual flour quality measurements generally indicated improvements with increasing chlorine treatment.

The volumes achieved by cakes made from Triticale flour, even at the best water and chlorine levels (C_2 W_1), were much lower than volumes reported for cakes made from a variety of soft wheat flours in the same lean-formula (Kissel, 1959, 1969; Wilson and Donelson, 1965). This would indicate that some quality factor in the flour, which was not markedly improved by chlorine treatment, limited the flour's capability to produce cakes of normal or large volumes.

The agreement between the two volume measurements used in this study was high, as indicated by a correlation coefficient of 0.91. Since the cross-sectional area measurement appeared to estimate cake volume accurately, was easier to perform, and likely was less destructive than rape seed displacement of the delicate cake texture, that measurement could be used alone to simplify experimental techniques without placing results in jeopardy.

Cake volume measurements are usually accepted as being indicative of crumb characteristics, with a large volume relating to a fine uniform crumb, and a lower volume to a coarse, uneven crumb. In this experiment, however, the subjective evaluation of crumb properties and volume measurements were not in close agreement, except in the response to liquid level in the batter, where a dramatic reduction in crumb score with increasing water in the cake formula paralleled the reduction observed in volume. As was the case with volume (Figure 9), there was less reduction in crumb score when the water level in the batter was increased from W_1 to W_2 than was observed with further increases in water level as indicated by the significant ($P<0.01$) quadratic effect of water level on crumb score (Table VI and Figure 11).

Cakes made from untreated flour received significantly ($P<0.01$) lower crumb scores than cakes made from chlorinated flour at the same liquid level (Table VI and Figure 12). Increasing chlorine treatment of the flour effected a significant linear improvement in cake crumb characteristics. Similar improvements in crumb characteristics brought about by chlorine treatment of flour have been noted by other workers (Sollars, 1958b; Wilson and Donelson, 1965; Miller

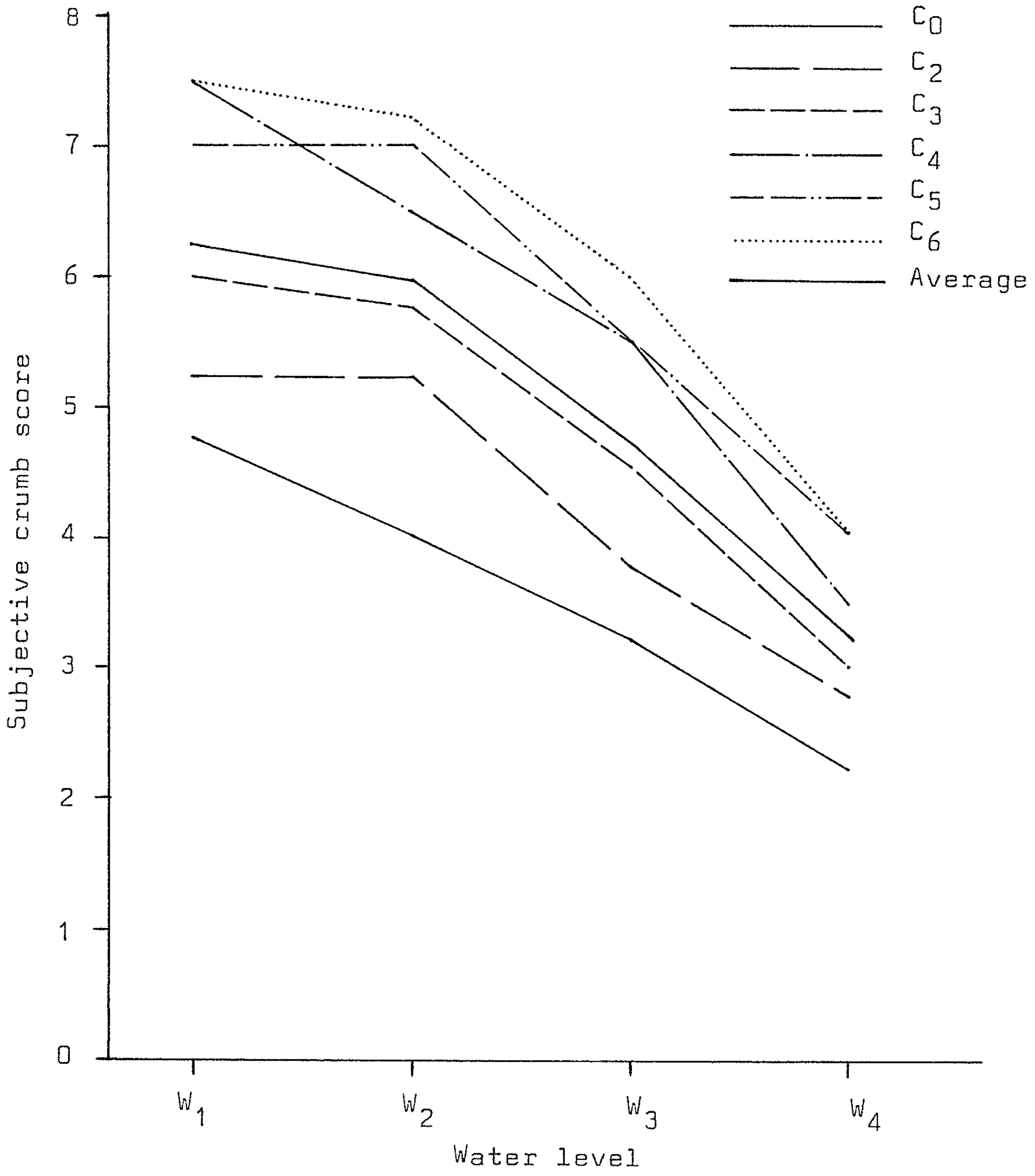


Figure 11. The effect of water level in the batter on subjective crumb score.

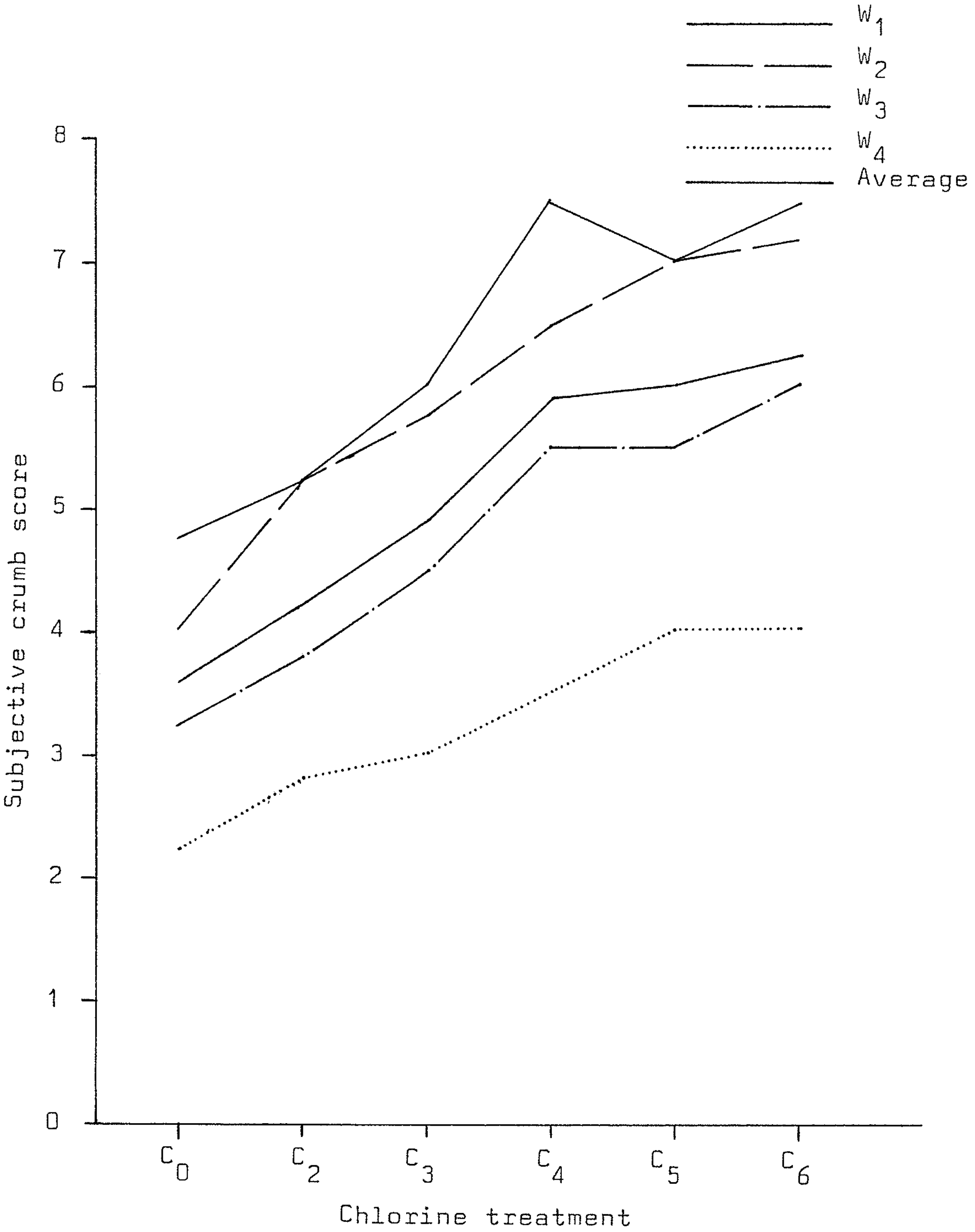


Figure 12. The effect of chlorine on subjective crumb score.

et al., 1967).

It was likely that the slightly improved pasting characteristics of the chlorine treated flour helped to stabilize the water in the fluid cake batter, preventing its separation during baking and consequently alleviating the formation of gummy layers which have been associated with batter settling (Miller *et al.*, 1967). The marked improvement in gelling ability of the flour (Table V) would have enhanced cake setting, and prevented collapse of the structure which is commonly seen during cooling in cakes made from unchlorinated flour. Both of these effects of chlorine on flour properties could have contributed to the observed improvements in cake crumb characteristics.

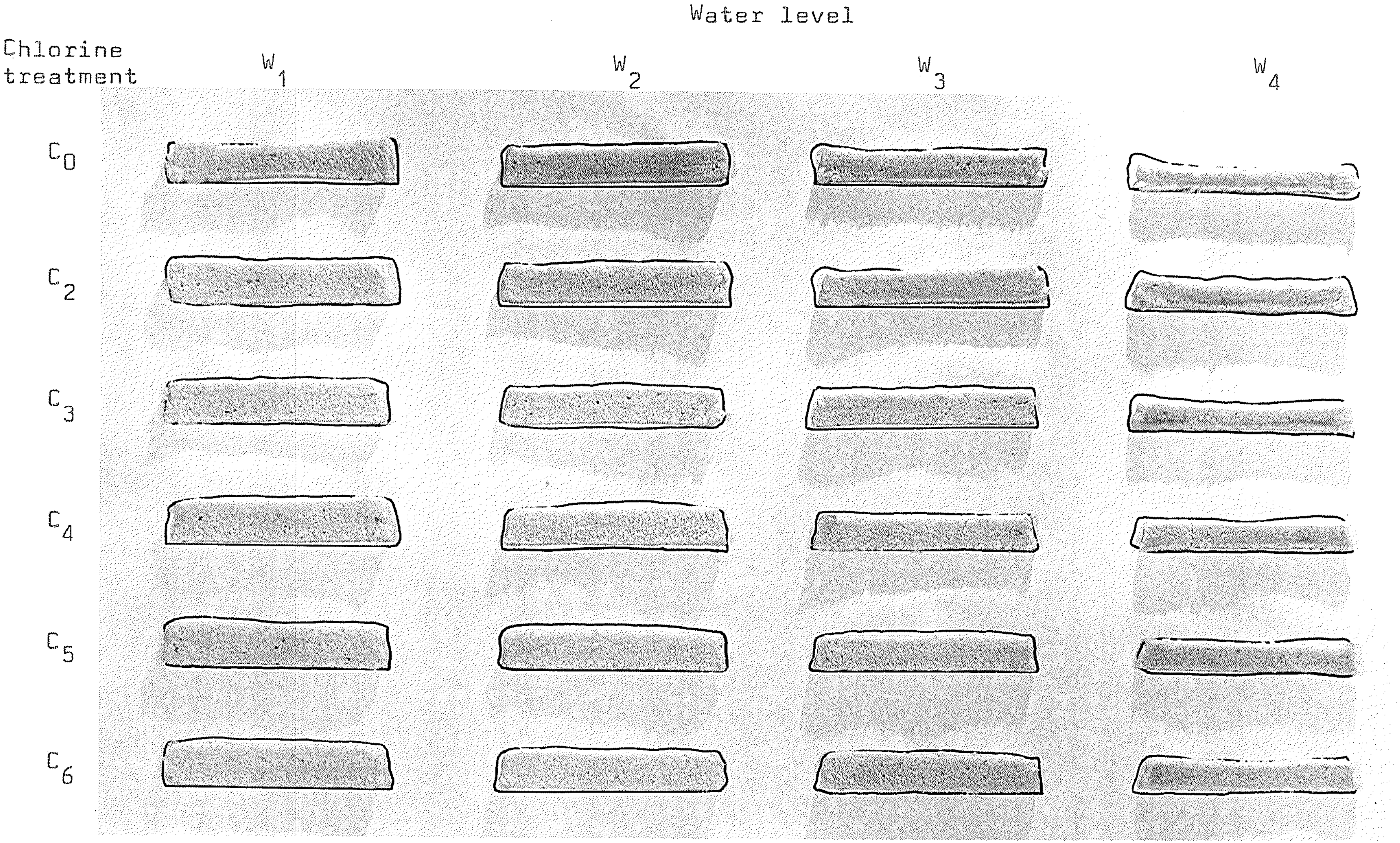
Although the tolerance of the flour to increased liquid levels in the cake batter was slightly improved by chlorine treatment, all cakes made at the highest liquid level (W_4) were unacceptable, with even the best chlorine level (C_6) yielding a cake with a coarse, soggy crumb and trace gummy layer. This indicates that W_4 was well beyond the optimum liquid level for Triticale flour, and the cake characteristics at this level can be ignored as they represent an extreme of quality, well beyond the range of practical usage.

Objective evaluations of crumb characteristics made with the Texturometer were not as neat as the subjective evaluation. This was possibly due to the unintentional bias of the experimenter in subjectively evaluating the crumb characteristics. However, as shown in Figure 13, the differences in crumb characteristics observed over water and chlorine levels were real.

Crumb firmness, measured on the Texturometer, increased in a linear manner with increases in the water level in the cake batter (Figure 14). With the exception of C_0, an increase in the water level from W_1 to W_2 had less effect on cake hardness than further increases. The evidence of the slightly increased tolerance to variations in liquid level displayed by all of the cakes made from chlorinated flour is one advantage of chlorine treatment.

Cakes made from chlorinated flour were significantly ($P<0.01$) softer than those made from untreated flour, however increasing levels of chlorine treatment brought about no change in crumb firmness (Table VII and Figure 15).

The differences in cake crumb softness between chlorinated and unchlorinated flour and among water levels likely reflected, in part, the volume differences among cakes. Since batters were scaled so that each layer contained the same amount of flour, sugar, shortening and leavening agent, and cakes made at lower water levels or with chlorinated flour achieved a larger volume, the standard one half inch sample taken for the Texturometer test would have



[1] Representative crumb characteristics of cakes photographed on a background of the original cross-sectional tracings.

TABLE VII

ANALYSIS OF VARIANCE OF OBJECTIVE EVALUATIONS OF CAKE CRUMB CHARACTERISTICS MADE ON THE TEXTUROMETER

Source	df	Hardness Mean Square	Cohesiveness Mean Square$\times 10^3$	Gumminess Mean Square	Adhesiveness Mean Square
Water	3	1305.0**	19.3**	549.1**	12.9**
W_{linear}	1	3682.7**	27.9**	1531.6**	35.6**
$W_{quadratic}$	1	231.9**	27.6**	115.6**	3.3**
W_{cubic}	1	0.4	2.4	0.1	0.0
Chlorine	5	29.3	13.7**	19.4*	1.9*
C_0 vs rest	1	136.6**	29.9**	85.6**	7.1**
C_{linear}	1	7.9	36.1**	9.9	2.3*
$C_{quadratic}$	1	1.4	0.7	0.7	0.2
C_{cubic}	1	0.1	2.2	1.1	0.0
$C_{residual}$	1	0.6	0.0	0.0	0.1
W x C	15	13.5	2.0	6.4	0.4
Blocks	2	97.6**	3.0	47.9**	3.3**
Error	45	12.3	2.8	5.8	0.4

**Significant $P < 0.01$.

*Significant $P < 0.05$.

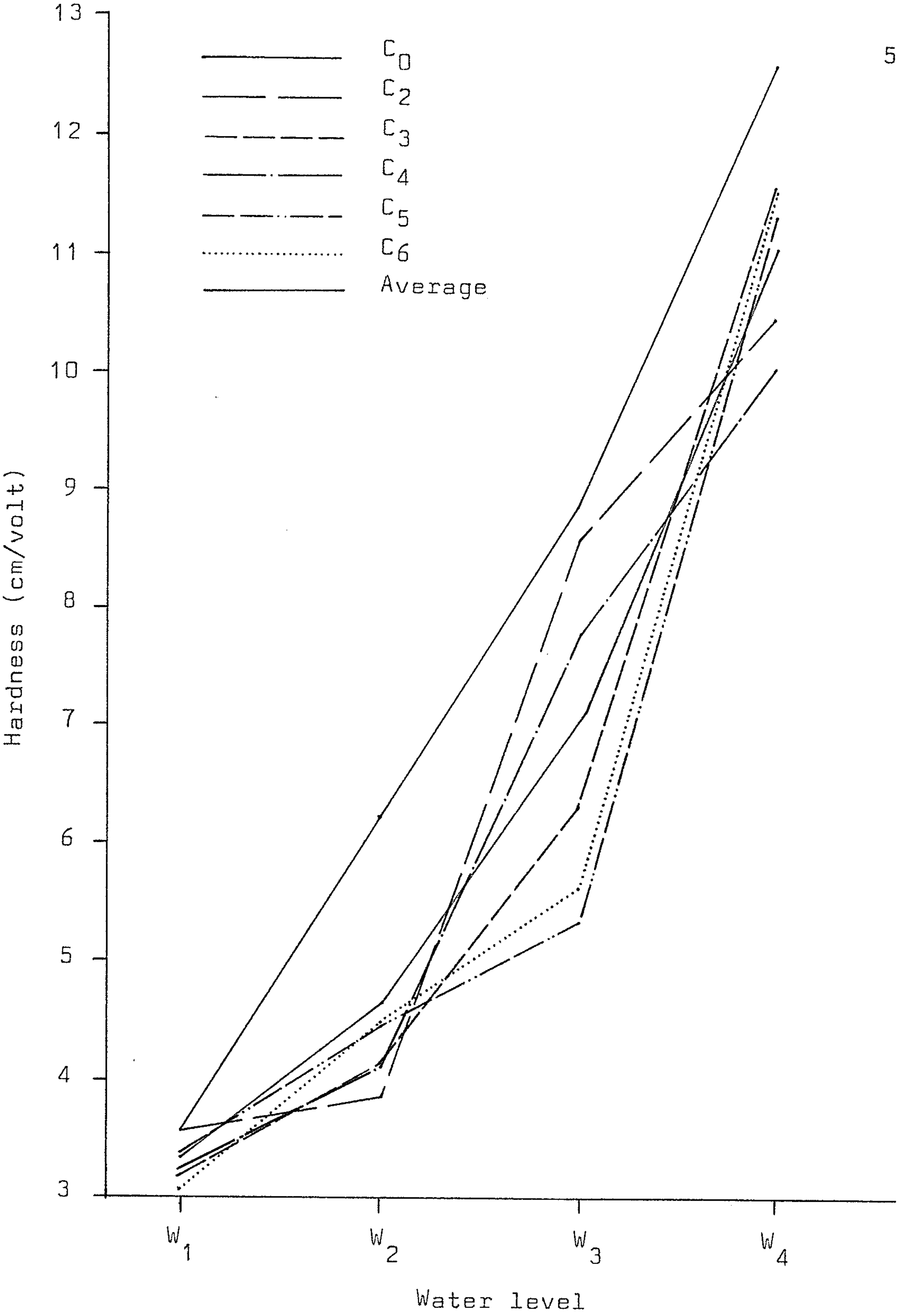


Figure 14. The effect of water level in the batter on crumb firmness measured on the Texturometer.

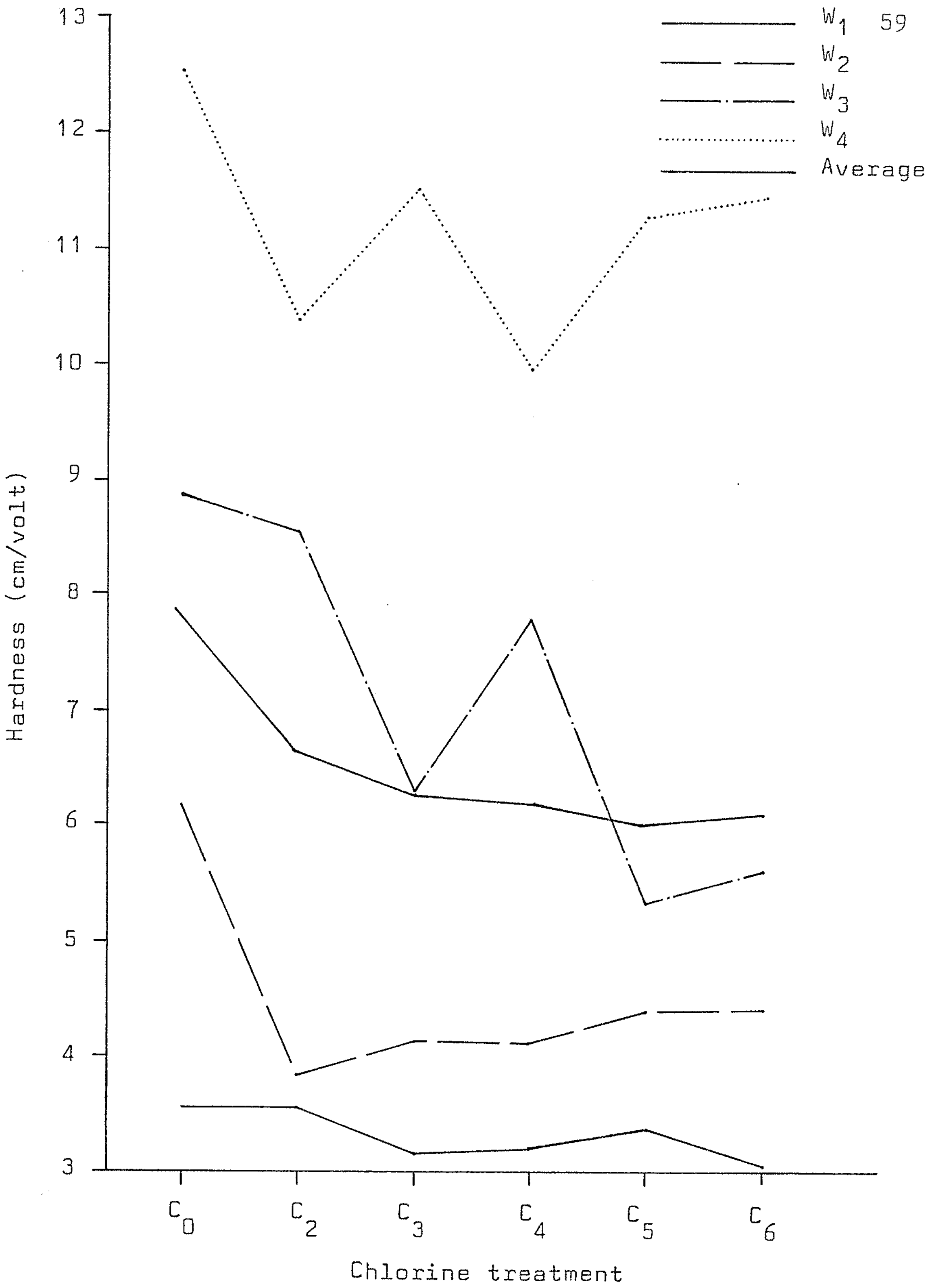


Figure 15. The effect of chlorine on crumb firmness measured on the Texturometer.

included a lower proportion of the structural ingredients, or would have been less dense than samples taken from cakes made at higher water levels or from unchlorinated flour which had smaller volumes. The less dense samples taken from cakes of larger volumes would have offered less resistance to compression or would have been softer. However, volume differences cannot be entirely responsible for differences in softness as cakes made from flour chlorine treatment C_2 achieved the largest volume but were not always softer than cakes made from flour treated with other levels of chlorine.

The second objective measurement of crumb characteristics taken from the Texturometer test was cohesiveness. Foods which are highly cohesive are ones with strong internal structures which are difficult to break down in the mouth during mastication or on the Texturometer during repeated chews.

As can be seen in Figure 16, the cohesiveness data was quite variable, however differences were still evident. As the water level in the cake batter increased, the cake samples became significantly less cohesive ($P < 0.01$). The most significant drop occurred between W_1 and W_2, and thereafter there was little change, with W_4 being perhaps slightly more cohesive than W_2 or W_3.

It was likely that cohesiveness values were related

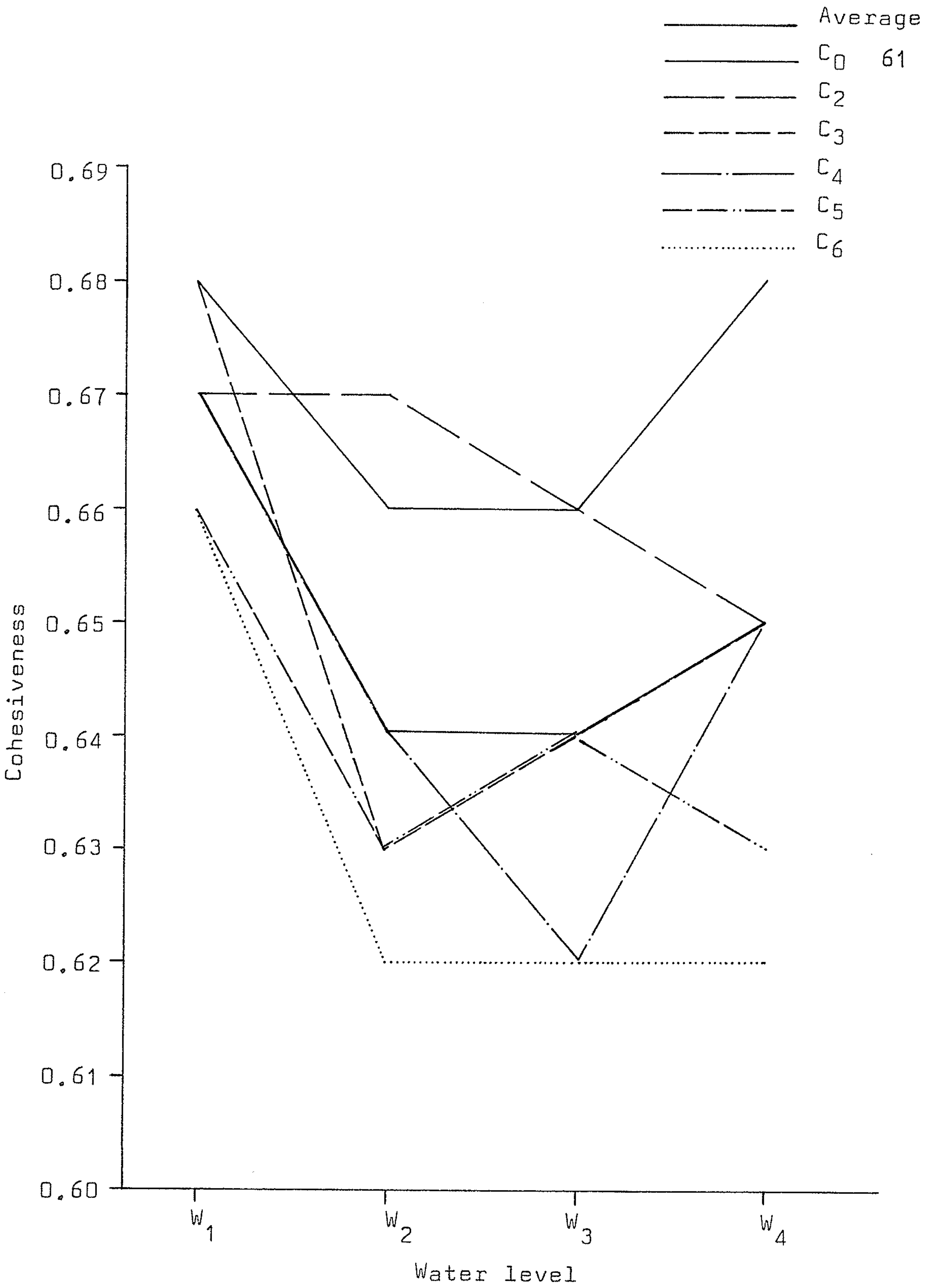


Figure 16. The effect of water level in the batter on cake crumb cohesiveness measured on the Texturometer.

to the marked volume and texture differences over water levels. At W_1, the cake samples were lighter, more porous and cake-like in texture. After the first compression stroke, the cake sample sprang back into near its original size, and thus the second compression stroke involved almost the same amount of work, indicating that the cake was highly cohesive.

At the higher water levels, W_2 and W_3, the cakes' more dense, compact structure stuck together on the first compression stroke. Because the cake did not spring back, the second compression stroke was accomplished with proportionately less work. An examination of the Texturometer curves indicated that cakes made at W_1 were more springy than cakes made at higher water levels, which, in part supports the above explanation.

At the highest water level, the samples were very dense, resembling a stiff gel rather than a porous cake texture. The slight increase in cohesiveness for cakes made at W_4 may have been due to the fact that since the samples were initially gel-like and dense, the first compression stroke did not alter their structure appreciably and proportionately more energy was required on the second stroke to compress the sample than in the case of W_2 or W_3, whose more porous structure was slightly compressed on the first stroke.

With respect to chlorine treatment, the unbleached flour yielded cakes which were significantly ($P < 0.01$) more cohesive than cakes made from bleached flour, and increasing levels of chlorine significantly ($P < 0.01$) reduced the cohesiveness of the cakes (Table VII and Figure 17). Since the effect of chlorine on cake volume was less marked than the effect of water level, presumably the cakes made at any one water level were of approximately the same density, or compactness. The reduction observed in cohesiveness with chlorine treatment would then likely indicate a more fragile internal structure in the cake samples rather than changes in the sample compactness.

Gumminess, defined instrumentally as the mathematical product of cohesiveness and hardness, reflected the differences seen in those two parameters. With increasing water levels in the cake batter, a marked linear increase was observed in gumminess, with less change in gumminess resulting from an increase in water from W_1 to W_2 than with further increases (Table VII and Figure 18).

Also as can be seen in Figure 18, cakes made with untreated flour were significantly ($P < 0.01$) gummier than cakes made with bleached flour, and showed less tolerance to increasing liquid levels in the cake batter. As was the case with the hardness measurement, there was no difference in gumminess among cakes made from the five chlorine flour treatments (Figure 19) indicating that as long as the flour

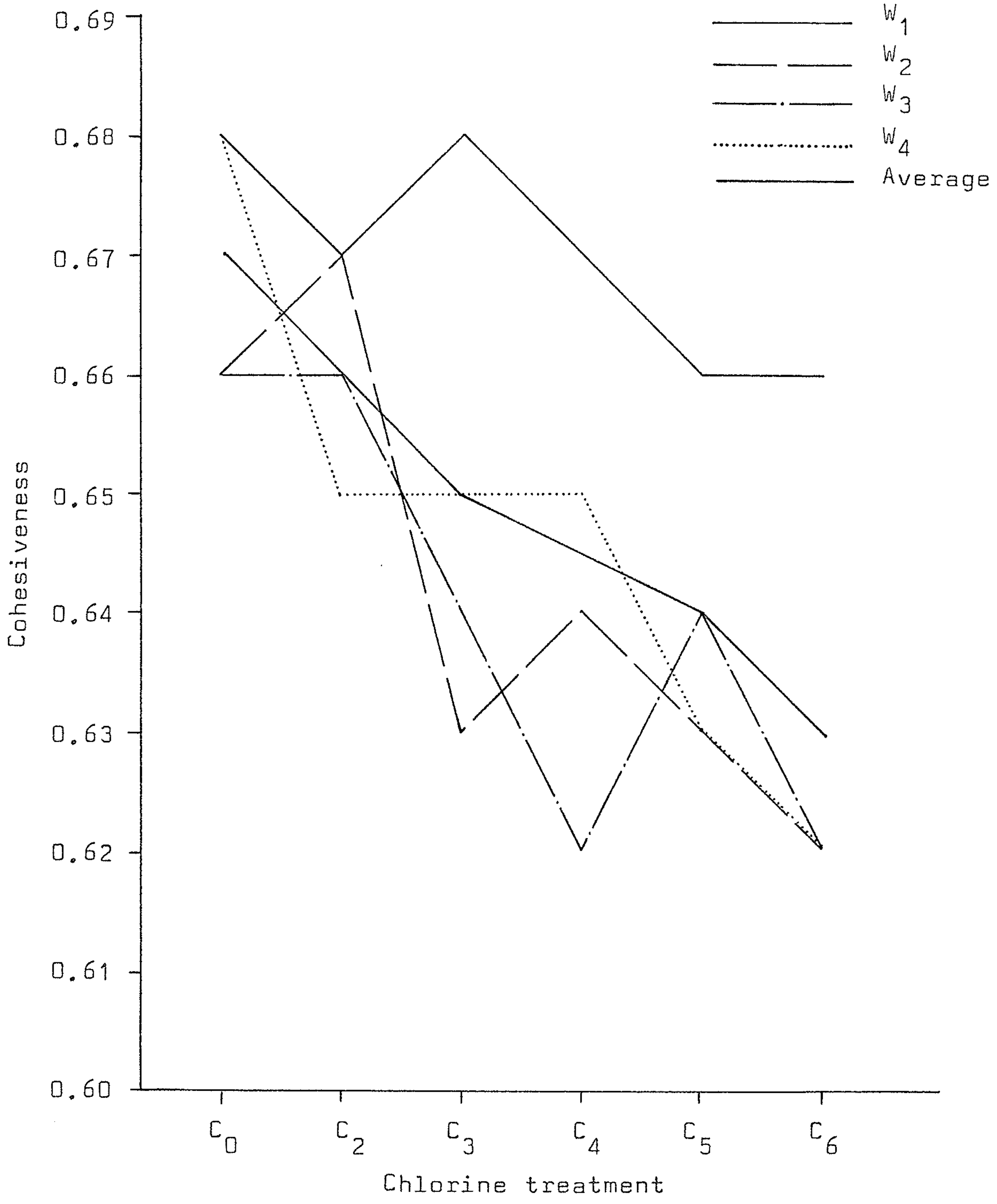


Figure 17. The effect of chlorine on cake crumb cohesiveness measured on the Texturometer.

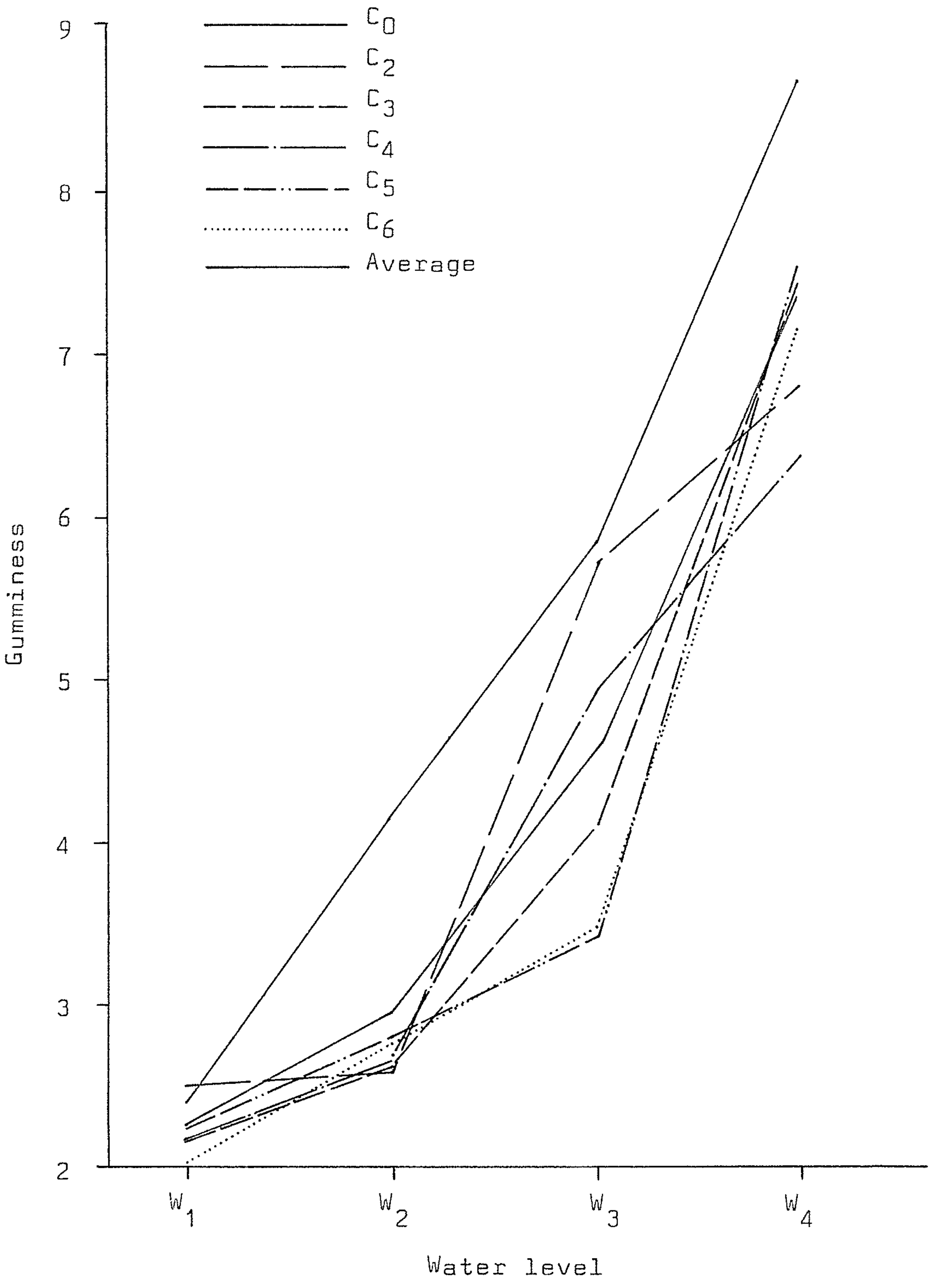


Figure 18. The effect of water level in the batter on gumminess of cake crumb measured on the Texturometer.

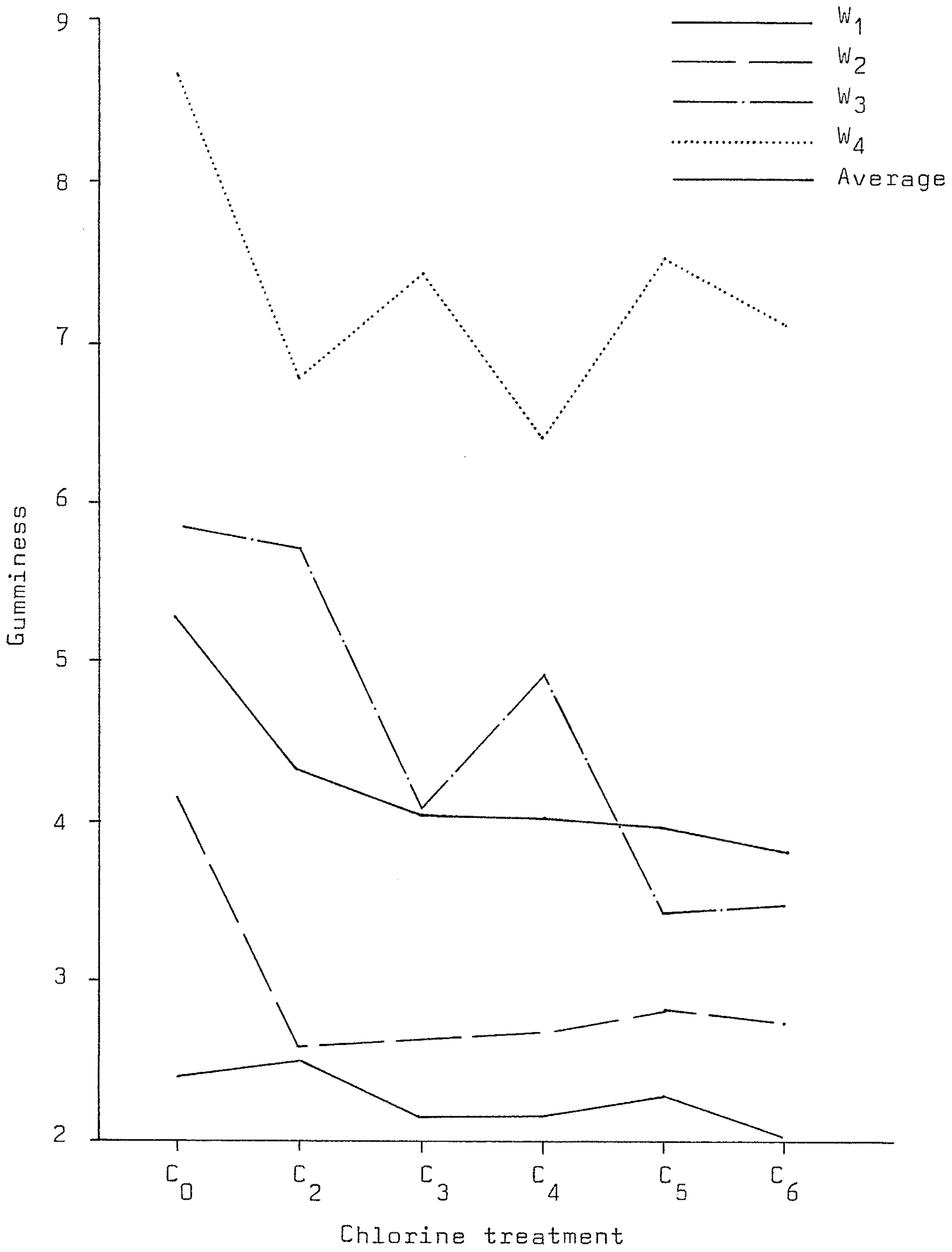


Figure 19. The effect of chlorine on gumminess of cake crumb measured on the Texturometer.

was chlorinated, the level of treatment had little effect with respect to crumb gumminess.

The final measurement of cake quality taken from the Texturometer test was adhesiveness or stickiness of the crumb. Similar to other Texturometer measurements, increases in the water level in the cake batter resulted in a significant increase in adhesiveness ($P < 0.01$) with an increase in water level from W_1 to W_2 causing less change than further increases (Table VII and Figure 20).

With the exception of W_1, the effects of chlorine on adhesiveness were much more dramatic than its effects on other objective texture measurements. Cakes made from untreated Triticale flour were significantly ($P < 0.01$) stickier, on the average, than cakes made from chlorinated flour, and also showed much less tolerance to increasing water in the batter (Figure 20). As shown in Figure 21, increasing levels of chlorine treatment, C_2 to C_6 effected a continual linear reduction in crumb stickiness at all but the lowest water level.

Since the adhesiveness response to changes in water level and chlorine treatment appeared to relate more closely than the other objective texture parameters measured to the subjective crumb scoring, it may be a more valid estimate of cake texture than hardness, cohesiveness, gumminess or volume measurements.

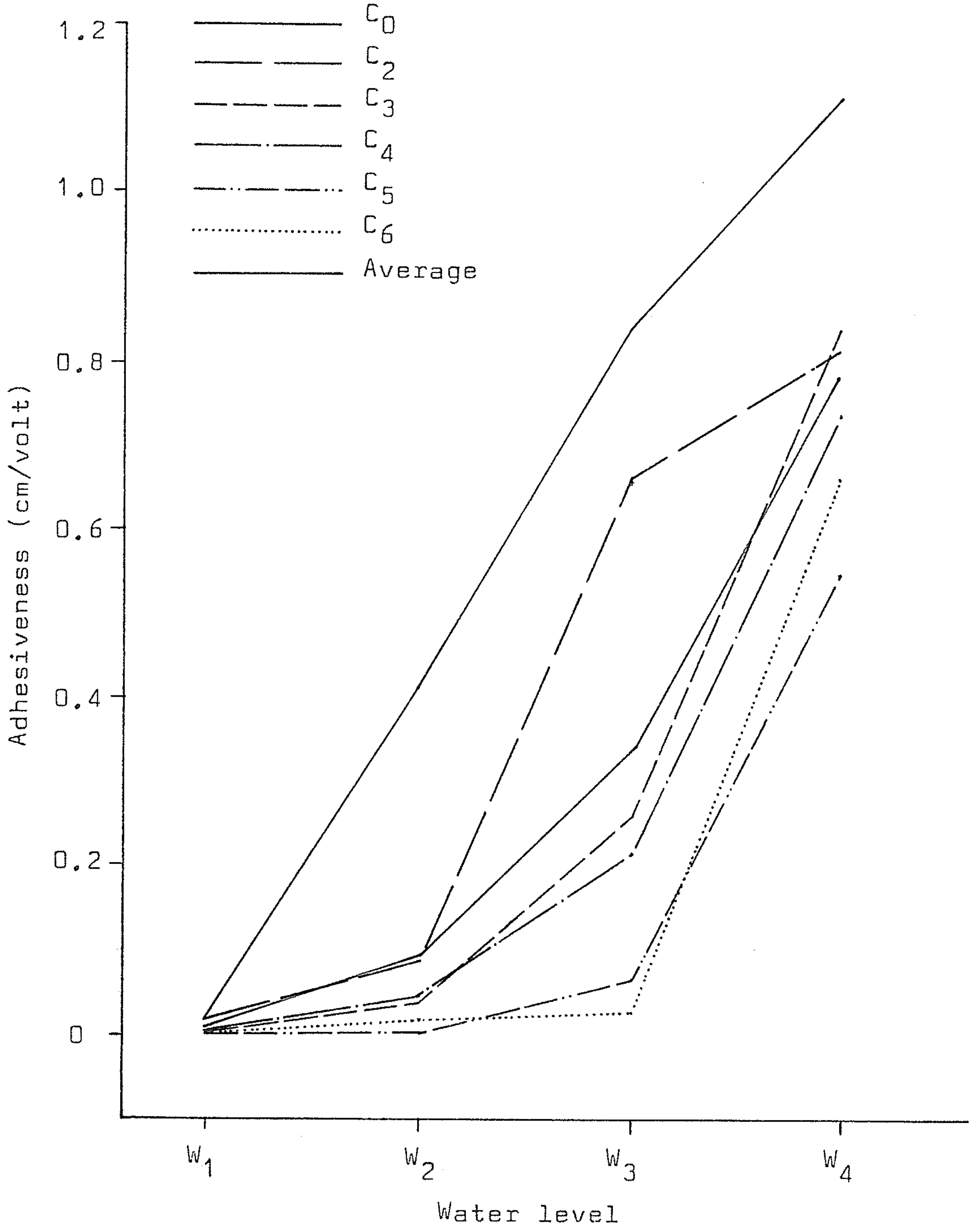


Figure 20. The effect of water level in the batter on adhesiveness of cake crumb measured on the Texturometer.

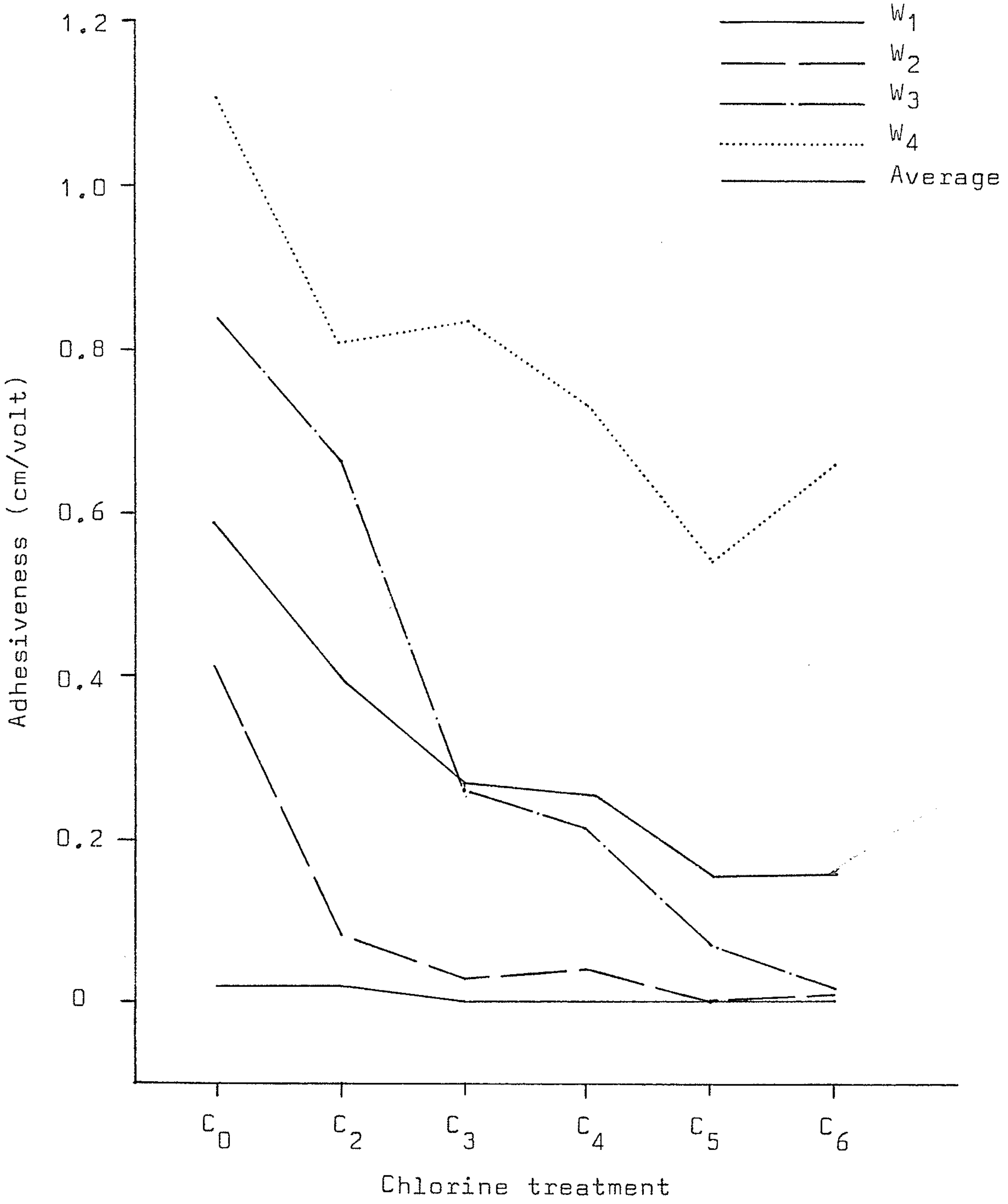


Figure 21. The effect of chlorine on adhesiveness of cake crumb measured on the Texturometer.

All of the Texturometer parameters measured except cohesiveness showed a significant difference between blocks (Table VIII). Since the tests were carried out on frozen, stored cakes, the differences between blocks was due to age of cakes and duration of frozen storage, with the first blocks of cakes being stored slightly longer and being slightly older than cakes from the succeeding blocks. Generally, the longer the cakes were held in frozen storage before testing, the firmer, gummier and stickier they became. These results point out the desirability of testing cakes in the fresh state in future experiments to alleviate factors which might confound the experimental results.

Another source of variation which arose in all the Texturometer data except cohesiveness was between the two cakes made from a single batter treatment. The significant differences in hardness, gumminess and adhesiveness between cakes from one batter would indicate that there was some difference in the batter poured into the two pans. These differences possibly arose due to the batter settling between mixing and scaling or due to undermixing the bottom portion of the batter. In future experiments utilizing the lean-formula cake, further alterations in the mixing method should be investigated in an attempt to eliminate these differences.

Since cohesiveness did not show the above differences

TABLE VIII

ANALYSIS OF VARIANCE OF SAMPLING EFFECTS IN TEXTUROMETER DATA

Source	df	Hardness Mean Square	Cohesiveness Mean Square$\times 10^3$	Gumminess Mean Square	Adhesiveness Mean Square
Blocks	2	97.6**	3.0^{ns}	47.9**	3.32**
Pans within treatments	71	11.2**	1.3^{ns}	5.0**	0.17**
Samples within pans	284	1.5	2.2	0.3	0.01

**Significant $P < 0.01$

ns - not significant.

which were evident in all the other Texturometer parameters measured, one must assume either that it is not affected by frozen storage and differences between batters, or that variability within the data masked these differences. If the latter alternative was true, which seemed to be the case, the cohesiveness data, in this experiment, must be considered a less valid or reliable indicator of cake quality.

Quality of cakes made from Triticale flour as indicated by volume estimates, subjective crumb score and objective Texturometer measurements, was depressed by increasing the liquid level in the batter. Preliminary work indicated that water levels lower than those used in this experiment were detrimental to cake crumb characteristics. It was likely that the lowest water level used was optimum for Triticale flour in the lean-formula cake. In contrast with optimum liquid levels of from 106 to 115% (flour basis) observed for a variety of soft wheat flours in the same lean cake formula (Kissel, 1959; Wilson and Donelson, 1965), the optimum liquid level for Triticale flour at 90% (flour basis) represents a considerably lower liquid carrying capacity.

At the optimum liquid level (W_1) chlorine definitely improved both cake volume and subjective crumb score, but the effects on objectively measured crumb characteristics were minimal. Some decrease in cohesiveness was evident at W_1 with chlorine application, but there were no marked improvements in crumb firmness, gumminess or adhesiveness.

However, when a panel of six experienced tasters ranked W_1 cakes for gumminess, C_0 was significantly gummier ($P < 0.01$) than the rest (Table IV), while increasing chlorine treatments tended to be decreasingly gummy. Gumminess is defined objectively as a product of hardness and cohesiveness (Friedman *et al.*, 1963). It was likely that the sensory panelists, with limited training considered both these texture parameters and adhesiveness to arrive at their decision. These sensory results suggest that the Texturometer was not adequate to describe the crumb differences detected at W_1 in this experiment.

One point from the sensory data is worth further note. The cake made from the C_5 treatment was ranked out of order (Table IX). This treatment was also atypical in alpha-amylase activity and in gel firmness measurements (Table V), which gives further support for linking these measurements with crumb characteristics.

In addition, the six member sensory panel's color rankings indicated that with increasing chlorine treatment, the cake crumb became significantly whiter (Table V). This is in agreement with the objective measurement of flour color (Table V), where chlorine effected a bleaching action on the flour pigments.

The dramatic improvements in the gelation

TABLE IX

THE EFFECTS OF CHLORINE ON GUMMINESS AND COLOR OF CAKES MADE AT THE OPTIMUM LIQUID LEVEL (W_1)

Average ranked value[1]	Flour chlorine treatment					
	C_0	C_2	C_3	C_4	C_5	C_6
Gumminess[2]	1.08^{a}	2.92^{b}	4.08^{bc}	4.42^{c}	3.58^{bc}	4.92^{c}
Color[3]	1.00^{a}	2.17^{b}	3.08^{c}	3.75^{d}	5.33^{e}	5.67^{f}

[1] Values in the same row not bearing the same superscripts are significantly different ($P < 0.01$).

[2] Average of 12 values; 1 = most gummy, 6 = least gummy.

[3] Average of 24 values; 1 = most yellow, 6 = least yellow.

characteristics of Triticale and the small reduction in alpha-amylase activity with chlorination were likely responsible for the improvements observed in the cake texture. However, even the best cakes at the lowest water level had much smaller volumes than comparable cakes made from soft wheat flours.

It was likely that amylase activity in Triticale, which was high in comparison with other soft wheat flours, and which was not reduced appreciably by chlorine, limited the ability of chlorine to effect marked improvements in the final cake quality, or to improve the tolerance of Triticale to increased liquid levels.

It is suggested that future work be carried out in which an attempt is made to further reduce the alpha-amylase activity in Triticale grain. This would expand its potential as a human food through additional improvements in the texture of baked products.

SUMMARY AND CONCLUSIONS

The cake baking quality of Triticale flour treated with chlorine gas at six rates, 0, 0.2, 0.3, 0.4, 0.5 and 0.6 ml/g flour, was assessed by physical and chemical measurements of flour quality, and by the performance of the six chlorine treatments in a lean-formula cake made at four water levels.

Increasing chlorine treatment decreased the flour pH and caused a slight reduction in alpha-amylase activity as measured viscometrically and in the amylograph. A marked increase in the firmness of Triticale flour gels, measured on the Texturometer, indicated improved gelation characteristics of Triticale starch with increasing chlorine treatment. Absorbance of water saturated n-butanol extracts of the flour indicated increasing levels of chlorine gas exerted a bleaching action on the flour pigments which was confirmed by the sensory panel's ranking of cake crumb color.

Treatment of Triticale flour with chlorine improved its performance in the cake-baking trial as indicated by a significant improvement in volume, subjective crumb score and Texturometer parameters of hardness, cohesiveness, gumminess and adhesiveness in cakes made from chlorine-treated flour versus untreated flour. However, the effects of increasing levels of chlorine, C_2 to C_6, on cake quality were more variable, bringing about improvements only in the subjective crumb score and in Texturometer measurements of cohesiveness and adhesiveness.

Increasing levels of water in the cake formula were detrimental to cake volume, subjective crumb score and Texturometer parameters of hardness, gumminess and adhesiveness. However, in the quality parameters of subjective crumb score, and crumb firmness, gumminess and adhesiveness, cakes made from chlorinated flour showed more tolerance to increasing water levels in the cake batter.

With the exception of volume and subjective crumb score, improvements in cake characteristics due to chlorine, which were evident when examining all water levels together, were minimized at the optimum water level (W_1). That is, the chlorinated samples, C_2 to C_6, were not markedly superior to C_0 at this water level, and cohesiveness and adhesiveness, which showed overall improvements with increasing chlorine treatment, were not altered by chlorine at W_1.

Although textural differences among cakes appeared to be minimized, the improving effects of chlorine at the best water level were still evident to a six-member sensory panel. C_0 cakes were ranked as significantly gummier than cakes made from chlorinated flour, and increasing chlorine tended to effect a reduction in crumb gumminess.

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