EFFECT OF NITROGEN, SULFUR, AND POTASSIUM CHLORIDE FERTILIZATION ON THE BAKING QUALITY OF SOFT RED WINTER WHEAT

by:

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(ABSTRACT)

Soft red winter wheat (Saluda c.v.) was fertilized using three treatments; urea, urea + KCl, and urea + sulfur. The wheat was harvested and milled and the flour produced was used to evaluate the baking quality of the wheat. Objective tests were performed on the flour samples. Significant differences in flour analysis were found among the three treatments. Farinograph curves for all treatments had medium peak time and short stability giving all samples hard red winter and hard red spring wheat characteristics. Flour from nitrogen treated grain was most tolerant to mixing and was significantly a stronger flour according to its mixing tolerance index (MTI) value, peak time value and absorption value. Flour treated with KCl had mixed characteristics; absorption and peak times gave it strong flour characteristics, while MTI value gave it medium strength characteristics. Sulfur treated flour exhibited medium strength characteristics. Ash results demonstrated

that KCl treatment had significantly higher ash content and was not suitable for cake batter. All treatments had higher protein contents than those characteristic of cake and cookie flours. Yellow cakes were baked for all three treatments and objective and sensory tests were performed. The flour treated with nitrogen and KCl produced cakes of low quality, sunken structure, dense in texture and low in volume. Cakes made with sulfur treated flour retained their structure and had the highest volume, but the texture was still dense. Sensory panelists found cakes made from sulfur treated flour lighter in texture than KCl and nitrogen treatments. Cakes from nitrogen treated flour were perceived as being denser than the rest.

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1.0 INTRODUCTION AND OBJECTIVES:

Agronomists reported improved crop yield with the application of all three types of fertilizer (Beaton,1966). However, for the consumer it is important that the flour resulting from grain treated with these fertilizers has acceptable qualities for baking. Conforti (1989) noted an increase in flour percent protein as total nitrogen fertilization increased. However, timing of application of nitrogen fertilizer to grain had no effect on protein content. Conforti (1989) also found a significant difference in the protein content of flour as a result of fertilization. Protein content is the major contributor to the baking quality of flour. An increase in protein content of the flour causes a decrease in the volume of the angel cake (Conforti,1989). The overall objective of this study was to evaluate the baking qualities of flour from soft red winter wheat treated with nitrogen, nitrogen and potassium chloride (KCl) and nitrogen and sulfur (S). The objective was accomplished by:

1) Evaluation of rheological properties of dough from the three treatments.

2) Evaluation of baked product (cake) by performing appropiate objective and sensory tests.

2.0 LITERATURE REVIEW

2.1 Soft Wheat Characteristics

Wheat and rice are the most important sources of caloric intake by many people in the world. Wheat is grown on every continent. The three most important species from the standpoint of production and for food use are; Triticum aestivum (common wheat), Triticum Durum (durum wheat), and Triticum Compactum (club wheat).

Common wheat comprises by far the largest proportion of the types and classes of wheat grown. Cultivars of the species are adapted to a wide range of climactic conditions. Cultivars are distinguished by certain kernel characteristics, some have red or brownish, others have white or yellow seed coats. Some have hard (or vitreous) and others soft (mealy) kernel texture. The terms "soft wheat" and "hard wheat" are applied to grain having soft and hard kernel structure, respectively, although the terms may refer in certain parts of the world to common and durum wheats, respectively. Very often kernel texture is a cultivar trait, although environmemtal factors may modify texture (Berg, 1951). Ground, soft wheat grain yields large quantities of finely granulated flour, whereas hard wheat grain yields a coarser product under similar grinding conditions. The difference in fracturing behavior between

endosperms has been attributed to the presence of a protein material on the surface of starch granules of hard wheat cultivars (Simmonds, 1974). This material adheres to endosperm protein to the starch surface within the cells. The adhesion is very strong therefore when stress is applied to the hard wheat endosperm, fracturing takes place along cell walls rather than through cell contents. Soft wheat endosperm under similar stress, fractures across cells, releasing cell contents. The starch granules can be separated easily from the protein matrix; therefore, the flour contains large quantities of free starch granules.

In some parts of the world such as the United States, Canada, Japan and Australia the term soft wheat is used for flour utilized for the making of cookies, biscuits, cakes, saltines, noodles and similar items. The properties of soft wheat are considered uniquely advantageous for the production of such goods for which product tenderness is important (Yamazaki et al., 1981).

Winter wheats are planted in the fall in regions where winters are only moderately severe and relatively dry. They begin to grow prior to the onset of cold weather, become dormant during cold weather, and resume their vigorous growth in early spring; they attain maturity in early summer. Soft red winter wheat is growned chiefly in the eastern states, with largest acreages in Ohio, Missouri,

Indiana, Illinois, and Pennsylvania. Protein content for soft red winter wheat ranges from 8.8-11.1% and has an average of 10.3% (Pyler, 1971).

2.2 Flour Quality

According to Pratt (1971), flour quality is defined as the ability of a flour to produce an attractive end product, with uniform good processing and baking properties.

Soft wheat flour appears to be uniquely suited for the baking of cakes, wafers, pretzels, cake doughnuts and similar products. Soft wheat flour gives products that are more tender, larger in size, greater in volume and of superior internal structure as compared to those from other classes of wheat (Yamazaki and Lord, 1971). Pratt (1971) classified flours by the quality criteria used for specific end uses. Some quality components which contribute to soft wheat flour characteristics are protein content, water absorption capacity (farinograph) ,and ash content.

Protein quantity and quality are considered to be primary factors in measuring the potential of a flour in relation to its end use.

Final product end use using wheat class and flour protein content as a quality measure is as follows: for layer cakes a soft wheat flour with 7-8.25% protein is recommended; for high ratio cakes, 7-8% protein, and for

foam cakes, 5.5-7.5% protein is recommended with a blend of soft wheat and hard wheat flours (Pratt, 1971).

Water absorption capacity is an important factor in the production of all types of baked goods. Usually high absorption values are desirable since they tend to increase with yield of goods. Absorption is measured in the laboratory by the farinograph which gives an indication of the amount of water required to yield a batter or dough of predetermined consistency. In relation to the flour end use, good flour for the making of layer cakes will exhibit low water absorption of 48-52%, for high ratio cakes low water absorption of 46-52% and for foam cakes a very low water absorption of 44-48% (Pratt, 1971).

Ash is another quality component that contributes to soft wheat flour characteristics. Flour to be used in the baking of layer cakes should have ash contents between 0.34-0.38%, flour for high ratio cakes 0.30-0.36% and for foam cakes 0.29-0.33% (Pratt, 1971).

2.3 Fertilization of grain by sulfur

Sulfur is a plant nutrient ranking in importance with nitrogen(N),potassium (K) and phosphorus (P). Sulfur fertilization has been shown to give crop responses equal in magnitude to those of N,P,K. According to Tisdale (1971), soil deficiencies are increasing throughout the

world. Unless sulfur is included with fertilizer materials, growers will not get the expected responses to applied N,P, and K.

Benefits derived from S fertilization can be grouped basically in three classes; crop yield increases, improvement in crop quality, and control of certain plant diseases. Increases in crop yields are perhaps the most immediate apparent result of sulfur fertilization. Increased growth and improved appearance of the plant are most quickly and easily noted by the grower (Beaton, 1966; Beaton and Tisdale, 1971).

Sulfur fertilization under certain conditions can have a pronounced effect on crop quality (Beaton, 1966). While quality factors may be less dramatic than yield increases, they are no less important. In some situations quality factors can, in fact be even more important to the grower than yield increases. Some of the quality factors that are affected by sulfur fertilization are protein content and quality, and baking quality of wheat.

Sulfur exerts a positive influence on the control of plant diseases. Several field experiments have shown that sulfur fertilization may eliminate or reduce the severity of certain plant diseases. There is strong evidence that the application of ammonium bisulfite reduced the incidence of

root rot on winter wheat in eastern Washington (Koehler, 1965). Kenaga (1974) also showed a control of fungal diseases in wheat by sulfur containing fertilizers.

2.31 Sulfur Deficiency

Sulfur deficiency has long been recognized as an important factor limiting the production of cereals, including wheat, in many parts of the world (Beaton, 1966). The effects of inadequate sulfur supply on wheat are; chlorosis of the leaves, reduced plant growth, lower grain yield and loss of grain quality (Wrigley et al., 1984). These effects arise because there is insufficient sulfur to contribute to cysteine and methionine synthesis, to take part in the enzymic processes of growth and growth regulation, or to form SH (sulphydryl) and SS (disulfide) groups which are important in governing the physical properties of the dough (Randall and Wrigley, 1980).

Sulfur deficiency of the grain is indicated by analysis with levels below 0.12% S (dry weight basis). Levels as low as 0.06% S have been reported for wheat grain grown in culture (Archer, 1974; Byers and Bolton, 1979). At the upper extreme sulfur contents of well over 0.2% have been obtained (Timms et al., 1981; Salmon, 1984). In another study, sulfur levels in the United

States field and glasshouse trials with sulfur fertilizer ranged from 0.11 to 0.18% (Brown,Wesley and Bitzer, 1974).

2.32 N:S Analysis (Nitrogen to Sulfur Ratio)

Another way a sulfur deficient grain can be identified, is by measurements of sulfur concentration in relation to nitrogen concentration. Wheat requirements for S depend on applied N(nitrogen) rates (Ramig et al., 1975) and on individual soil and plant balances of N and S. N to S relations, both in plant synthesis of protein and in organic matter (plant residues) transformations, influence N to S interaction effects on wheat yield in the field (Koehler, 1965). According to Beaton (1980), 10 lbs/A of sulfur are required per wheat yield of 40 bu/A. Thus N to S ratio in the grain is a more reliable indication of sulfur deficiency in wheat.

Quality loss from severe sulfur deficiency is probably less frequent than quality changes due to excessive nitrogen fertilization. Several groups of researchers have concentrated in the latter situation. Reports have described unexpectedly low quality for grain samples grown with increased levels of nitrogen fertilizer (Tipples et al.,1977; Bushuk et al.,1978; Johnson et al.,1984; Timms et al., 1981). A major cause of quality loss in such cases according to Timms et al. (1981) is insufficiency of sulfur

in relation to nitrogen. Two of the three samples they compared, produced gluten samples that behaved differently in a reconstituted dough baking test, the poorer quality being shown by the sample from intensive nitrogen fertilization (N:S ratio of 11).

A normal N to S ratio of 10-12 reflects the average level of sulfur at about 80-100 mg per gram of N. However, when sulfur is deficient, the ratio may rise to 20 or more. A ratio of 15-17 was suggested as a threshold index, beyond which loss of grain yield and quality would be expected (Byers and Bolton, 1979; Randall, Spencer and Freney, 1981; Salmon, 1984; Reneau,Brann, and Donohue, 1986). This ratio is close to the critical N to S ratio in wheat tops which varies from 15 to 19 depending on the plant age (Spencer and Freney, 1980).

If nitrogen and sulfur are available in the appropiate proportions, most of the sulfur is incorporated into protein, leaving a small remainder as sulfate and small organic compounds such as glutathione, thioctic acid, and other thiol molecules. If the supply of sulfur rises so does the accumulation of sulfate (Roberts and Koehler, 1965). Arrando et al. (1976) found that nitrogen and sulfur fertilization act synergically on wheat with a yield increasing up to 210%. A sole nitrogen fertilization also was operative, but limited to a 40% increase. On the

contrary, the sole sulfur treatment was without effect at all.

Moss et al. (1981) performed a field experiment on Olympic wheat to see how it responded in yield of grain to both sulfur and nitrogen. They reported grain nitrogen concentration responded mainly to nitrogen supply and ranged from 1.38 to 2.56%. Grain sulfur concentration was dependent upon both sulfur and nitrogen supply and varied from 0.08 to 0.18%. The marked interaction between N and S on yield parameters indicated that the effects of sulfur nutrition can not be considered without nitrogen.

2.33 Grain Quality, Dough Properties, and Baking Quality

Not only does sulfur deficiency reduce grain yield, it also causes the quality of the grain to deteriorate (Beaton, 1966). A fall in the levels of the essential amino acids, cysteine and methionine, would be expected if sulfur is deficient. An obvious consequence of the changes in amino acid composition accompanying sulfur deficiency is that the nutritional value of the grain is reduced (Wrigley et al., 1980; Rendig, 1984). The importance of cysteine/cystine in determining gluten properties and of cysteine and in particular methionine in influencing feed value of the grain, suggests that sulfur supply to feed crops should be important. Sulfur deficiency causes a redirection of

protein synthesis in the grain in favor of low sulfur proteins at the expense of high sulfur proteins (Timms et al., 1981; Wrigley et al., 1980; Yoshino and McCalla, 1966). Surprisingly, however, the levels of most other essential amino acids in the grain also fell severely when sulfur was deficient (Byers and Bolton, 1979; Wrigley et al, 1980). Small scale tests on low sulfur grain from sand culture experiments first indicated the adverse effects of sulfur deficiency on grain quality (Archer, 1974; Wrigley et al 1980). Subsequent experiments on field grown grain extended these conclusions to show severe reductions in bread making quality (Wrigley et al., 1980).

In Canadian field trials from 1941 to 1953, Rigby (1941) observed that loss of baking quality was associated with grain from sulfur deficient soil. Rigby found sulfur content to be a better measure of baking quality than protein. Yoshino and McCalla (1966) examined gluten content from sulfur deficient grain and predicted that compositional changes would severely reduce the suitability of the grain for dough formation and baking. The predcitions were largely based on the hypothesis of Frater, et al. (1960) that SH and SS bonds of gluten proteins play an important part in providing the viscolelastic properties of wheat dough (Frater et al.,1960).

Archer (1974) provided initial experimental evidence, based on the small scale Pelshenke test, that dough properties are poorer in grain from sulfur deficient plants. More evidence of poor dough properties from sulfur deficient grain was provided by the extensive quality evaluation of grain samples (cultivar Olympic) from the S and N fertlizer field trials (Randall et al., 1981; Moss et al., 1981) and from later field trials involving three varieties of different quality types Olympic, Egret and Shortim (Moss et al., 1983). Over a hundred samples were thus, provided ranging in sulfur content from 0.08 to 0.18%. In these studies, sulfur deficiency consistently produced harder doughs that were less extensible and more resistant to stretching, and loaves of smaller volume and poorer texture. Flour samples of Egret (a biscuit wheat) gave poorer cookie spread when grain sulfur was low.

Dramatic differences in baking quality due to sulfur deficiency were also demonstrated by Byers (1985). Differences between the three flour samples in their protein (nitrogen) contents might account for the different loaf volumes of the two sulfur fertilized samples, but not for the 50% loss of loaf volume in the sulfur deficient sample. Sotiriou and Kick (1983) also observed loss of baking quality potential in grain samples of low sulfur content compared to that of normally fertilized controls.

2.4 Sulfur Fertilization and Grain Quality

Salmon (1984) also concluded that foliar spray with urea was likely to lead to loss of grain quality, based on evaluation with the SDS sedimentation test. Both Salmon (1984) and Timms et al. (1981) noted that an increased amount of sulfur poor proteins (e.g. w-gliadins) accompanied quality deterioration. Such results suggested that quantitation of a critical group of proteins was needed as a diagnostic test.

In all these cases of sulfur related quality deterioration a change in the proportions of SH and SS bearing proteins was seen, so that at low sulfur levels, normal SH-SS interchange is altered and dough extensibility decreases. Baking quality was reduced as a result of these changes in dough properties and there may have been a reduction in high sulfur proteins that help to stabilize bread crumb during baking by SS bond arrangement (Schofield, Bottomley, Timms,Booth, 1983).

In summary, sulfur deficiency is emerging as a factor to be considered when examining grain samples with processing quality that is less than would be expected from their protein content and quality type. The potential of sulfur deficiency to reduce both yield and quality makes it a common interest of both grain producer and processor and

a target for attempts to produce a simple screening test to identify growing sites that require sulfur.

2.5 Fertilization of Grain by Potassium Chloride(KCL)

Since 1840, when Liebig published his book Die Chemie in ihrer Anwendung auf Agrikultur und Physiologie, potassium is known as a major plant nutrient. As most soils do not supply K in sufficient quality and rate to satisfy the needs of the crop, potassium has to be applied as fertilizer.

Very few investigations have been reported on the effect of K fertilization on yield and quality of wheat grain. Many fertilizer trials in Iran (Dewan and Famouri, 1964) showed that K did not increase yield of wheat. On the other hand, cereal crops have responded to KCl (muriate of potash) fertilization on soils testing very high in exchangeable K. North Dakota researchers showed grain yield and plumpness increased in six out of thirteen barley trials when KCl was applied (Zubriski et al., 1970). Extensive field studies in Montana resulted in a significant response to K containing fertilizers, 47% of the time for winter wheat, 30% of the time for spring wheat and 44% of the time for dryland barley (Schaff and Skogley, 1982).

Christensen and coworkers (1981) reported winter wheat grain yield increases from the application of chloride as NH_4Cl or KCl. They also reported a supression of take all

root rot due to Cl additions. It is uncertain whether cereal response to KCl is due solely to K. If yield responses are due in part to Cl, questions concerning rates and placement of KCl must be addressed. Fixen et al., (1986) conducted an experiment to determine if hard red spring wheat, spring barley, and spring oats would respond to KCl fertilization on high K testing soils to determine if responses were due to K or to Cl. A second objective was to determine the importance of seed placed KCl in maximizing wheat yield. Wheat yield increases from KCl ocurred at six out of fourteen sites over a three year period. Wheat and barley were more responsive to KCl than were oats. All responses occuring on soils testing very high in exchangeable K were apparently due to Cl in the KCl fertilizer. Grain yield increases were large enough to make KCl fertilization of these soils very economical, provided responsive sites could be predicted.

Chloride fertilizers have been shown to reduce the severity of infection in wheat crops by Puccinia striiformis and Septoria spp. in the United States (Christensen et al., 1982). In the United Kingdom the severity of infection by P. striiformis was reduced by chlorides in the glasshouse (Russell, 1978). Research has also shown that chloride will decrease the incidence of take all and stripe rust in winter wheat (Christensen et al., 1983; Jackson et al., 1983).

An experiment was carried out by Kettewell and Bayley (1987) to evaluate the effects of foliar application of KCl in the field on foliar and ear disease, and the consequences for yield and grain quality of winter wheat. Potassium chloride had a significant linear increase in flag green leaf area with increase fertilizer application. Yield and specific weight both increased significantly with increasing KCl rate, protein content was not affected.

James and Jackson (1984) saw greater yield response of Daw's wheat to increased amount of KCl applied. The data indicated the higher the soil potassium level, the greater the response of grai yield to soil pH. Also, the greater the application of KCl, the higher the test weight was. Although the requirement of crops for potassium has been known for decades, the functions of this nutrient in metabolism and yield formation are still subjects of intensive research.

2.6 Effect of Nitrogen Fertilization on Soft Red Winter Wheat

2.61 Grain Yield

Extensive research conducted in the United States demonstrated that grain yields of SRWW can be increased by intensifying crop and pest management practices. One of the primary requirements for these high yields is a dense and uniform stand. This results from careful manipulation of

management factors such as seeding rate, row width, seeding depth, and fertilizer treatment. The density of a wheat stand is determined by the number of plants established and the number of tillers developed on each plant. The number of plants is a function of seeding rate, and this can be controlled. The amount of tillering, however is greatly influenced by the environment and can not readily be controlled (Zeleny, 1971).

Seeding rate is controlled by the grower and should be adjusted for seed quality, planting date, and seedbed condition. Increasing seeding rate increases competition between plants within a row; but at a given seeding rate, reduced space between rows can be used to increase the distance between plants and decrease interplant competition. In Northeastern United States, the commonly used row spacing is 17.8 cm. but based on studies by Roth and coworkers, (1984), a row spacing of 12.7 cm. should give consistent increases in yield. In the United Kingdom, Holiday (1963) also reported an increase in yield with reduced row spacing.

Thin stands also may be caused by uneven emergence resulting from poor seeding depth control. Plants from too shallow seed placement form crowns near the surface and are susceptible to frost. Deeper seeding may increase crown depth and improve stand density and uniformity. A seeding

depth of 2.5 to 3.8 cm. is recommended to obtain proper seed coverage and satisfactory stands. (Roth et al., 1984)

The practice of using high rates of N fertilizer has increased in recent years, particularly in Europe, but it does not guarantee high yields (Campbell,Davidson, and Warden, 1977). At some point the N efficiency begins decreasing with increasing rates of N (Stanford and Hunter, 1973). Frederick and Marshall (1985) reported a decrease in kernel weight due to negative yield responses from high nitrogen rates. Decreased grain yields from excessive N application also have been associated with increased stress caused by excessive vegetative growth stimulated by N,(Frederick and Marshall, 1985; Roth et al., 1984) In Pennsylvania single applications of high nitrogen levels (>100 kgN/ha)in spring often resulted in excessive vegetative growth, increased levels of powdery mildew and reduced grain yields (Broscious et al., 1985). Positive responses to increased N levels are greater tiller density, more kernels per head and reduced kernel weight (Frederick and Marshall, 1985). Split or delayed spring N applications could improve the yield response to high N levels. Split and delayed N applications have some advantages. Fertilizer use efficiency can be improved when N application is delayed until growth stage 5 (Remy and Viaux, 1982), possibly due to reduced N losses from a shorter time between N application

and crop uptake. Delaying some N may reduce excessive tillering and subsequent lodging (Cooke, 1982).

2.62 Grain Quality

Various studies have shown that protein content of wheat may be increased markedly by nitrogen fertilization (Hucklesby, Brown, Howell, and Hageman,1971; Hunter and Stanford,1973). Long and Sherbakoff (1951) suggested that soft wheat quality was influenced by N fertilization, particularly when applied in the late stages of plant development. Late N application resulted in high protein content, low pearling index, and high gluten strength. Hucklesby et al. (1971) studied the effects of late N fertilization on protein content of Blueboy and Arthur soft red winter wheat varieties. Protein contents of 10.2, 14.6 and 16.1% were obtained with spring N application rates of 0,112 and 224 kg/ha, respectively. Hunter and Stanford (1973) studied the effect of nitrogen fertilization at different times and rates on SRWW Redcoat and Blueboy varieties. The average protein contents in the grain were increased from 10.9% with no N applied to 14.3% with N fertilizer applied at 168 kgN/ha. The higher fertilizer rate gave higher yields and higher protein contents which is not desirable for pastry and cake making.

Nitrogen fertilizers have different effects on the amounts of amino acids present in wheat grain. Nemeth and Kereszles (1969), Muler (1965), and Michael (1964) found that the biological value of the protein does not decrease as a result of N fertilizers, if supplemented with adequate amounts of P and K. Vincze and Szuts (1978) found that higher levels resulted in an increase in aspartine, glutamine, glycine, lysine and to lesser degree in serine, alanine, isoleucine, leucine, tyrosine and phenylalanine. No change was seen in proline, cysteine, methionine, histidine and arganine contents. Maximum amounts of tyrosine, isoleucine and alanine were observed when N was applied at 120kgN/ha- 160kgN/ha. Methionine and proline decreased at these higher levels of N fertilization.

Nemeth (1983) also showed a decreased in methionine and lysine with N fertilization. When P and K were applied with no N fertilizer, increased levels of methionine, lysine, valine, phenyalanine, and isoleucine in wheat protein were observed. Essential amino acids of wheat were lowest at 174kgN/ha and highest at 87kgN/ha.

Amino acid content has been reported to differ with cultivars (Nelson,Young, and Bitzer, 1978). Nelson et al. (1978) indicated that the protein quality and total amino acid levels were affected by the N levels. Depending on the

cultivar, the percentage of some amino acids were increased at higher N levels.

2.62 Baking Quality

Information on the influence of N fertilization on baking quality of soft red winter wheat is limited. Koenig and coworkers (1987), studied the influence of nitrogen fertilization on SRWW grain protein and its relation in the improvement of breadmaking properties of the flour. The application of different concentrations of N at two growth stages was found to be related to dough rheological properties as well as to the objective and sensory evaluation of the bread. The protein content showed a significant increase with nitrogen treatment in growth stages 25 and 30, 168+0 and 0+168 kg N/ha. As nitrogen fertilizer was added later in the growth stages of the wheat, the greater the increase in flour protein. Farinograph peak time, stability and time of breakdown were found to increase in treatments 168+0 kg N/ha and 0+168 kg N/ha. Again, it was seen that at the later stages of fertilizer application farinograph curves were found typical for a strong breadmaking flour.

Bruckner and Morey (1988) demonstrated that nitrogen rates in excess of 64 kg N/ha contributed to undesirable grain protein increases. Also, an excess N application

reduced SRWW milling and baking quality due to an increase in grain protein and endosperm hardness. Paredes-Lopez et al., (1985), studied soft and semihard soft wheats at three levels of nitrogen fertilization (0,110 and 220 kg N/ha). Grain N for each cultivar increased slightly at each level of application. At high fertilization level the proportion of essential amino acids of both cultivars went down. Baking properties of the wheat for both cultivars were improved with N application.

3.0 Methodology

The overall objective of this study was to evaluate the baking qualities of flour from soft red winter wheat (SRWW) treated with nitrogen, nitrogen (urea) and sulfur and nitrogen (urea) and potassium chloride.

3.1 Wheat

Saluda, a soft red winter wheat was grown by the Agronomy Department of Virginia Polytechnic Institute and State University in the 1987 and 1988 growing season. The experiment was established on a Guernsey silt loam soil (Aquic, Hapludalf, fine, mixed and mesic) in the Ridge and Valley region of Virginia (Alley and Scharf, 1989). Late season foliar treatments were used and the protocol by which wheat was grown and treated is shown in Table 1. A randomized complete block design with four replications was used. Foliar N applications could increase needs for sulfur of the plant; therefore, sulfur and nitrogen were applied in combination. Potassium chloride was included in this study to test the beneficial effect of chloride on yield by reducing disease (Alley and Scharf, 1989). The treatments were applied at growth stages 30, 37 and 45 (Zadoks,Chang, and Knozak, 1974).

TABLE 1. "SALUDA" WHEAT LATE SEASON APPLICATION OF NITROGEN , NITROGEN+KCL, AND NITROGEN + SULFUR, WITHOUT FUNGICIDES.

TREATMENTS[1]		
GS 30*	GS 37*	GS 45*
60N	15N(UREA)	15N(UREA)
60N	15N(UREA)+15KCL	15N(UREA)+15KCL
60N	15N(UREA)+20S	15N(UREA)+20S

*GS=growth stage (Zadoks,Chang, and Konzole,1974)
[1] GS 30 nitrogen was supplied with 30% UAN solution all GS 37, and GS 45 supplied with urea solution. All fertilizers were applied in the form of foliar spray.KCL and S treatments harvested in 1988, and Nitrogen harvested in 1987.

3.2 Flour Analysis

The flour was milled on a Buhler experimental mill by the American Association of Cereal Chemists (AACC) method 26-20,(AACC Handbook,1983) at Mid-State mills Newton, North Carolina.

3.21 Alkaline water retention capacity (AWRC)

Alkaline water retention capacity was tested using the method by Yamazaki and Donelson (1972).

3.22 Flour moisture content

Flour moisture content was evaluated by the AACC method 44-15A(AACC Handbook,1983),using the Brabender moisture tester (C/W Brabender Instruments Inc., South Hackensack, NJ).

3.23 Flour ash content

Flour ash content was determined using AACC method 8-01 (AACC Handbook,1983).

3.24 Protein and nitrogen content

Protein and nitrogen content of flour were determined using Kjeldahl analysis (Association of Official Analytical Chemists, AOAC, 1975). A conversion factor of 5.7 was use to calculate nitrogen content.

3.25 Rheological properties

Rheological properties of the dough were assesed using the Farinograph (C/W Brabender Instruments Inc., South Hackensack,NJ) by AACC method 54-21 Constant flour weight procedure for 50 gram sample (AACC Handbook, 1983). All tests were done in triplicate. Statistical analysis was performed using the SAS computer package (SAS Institute, Cary, North Carolina, 1982) using one way analysis of variance procedure and Duncan's multiple range test at probability < 0.05.

3.3 Cakes- Objective Measurements

Cakes were prepared from each of the experimental flours by the rules of Pyler (1973); 1) fat should not exceed the egg, 2) fat should not exceed the sugar, 3) sugar should not exceed the liquid. The formulation is shown in Appendix A,the preparation method and equipment are shown in Appendix B.

An incomplete balanced block design with three replications was used. For each replication, two cakes from one experimental flour were baked. Specific gravity of the batter was measured before baking. One cake was used for sensory evaluation and the other for objective measurements. Objective tests done on cakes 3 hours after baking were; volume of cake by rapeseed displacement, texture of the crumb, moisture as previously described,and crust and crumb color . Statistical analysis on cakes was performed by SAS (1982) with a one way analysis of variance and Duncan's difference test at $P < 0.05$.

Volume was measured by a rapeseed displacement method developed by Murano (Murano, 1989). The inside volume of the cake pans was measured.(length X width X height, in cm.) The pan was filled with rapeseed, and the excess scraped off with a ruler. The filled pan was weighed and weight recorded. All seeds were poured out and the pan reweighed.

The difference in weight was the weight of the seed to fill the pan. By using the interior volume of the pan and the weight of the seed that occupied the pan, the weight of one cubic centimeter of seed in grams was calculated.

The cake volume was based upon the amount of seed that was poured into the pan containing the cake. A cardboard collar was constructed to fit exactly on top of the pan. This extension allowed for the rising of the cake. The sum of the interior volume of the collar and of the volume of the cake pan was recorded. Plastic wrap was placed over the cooled cake. The collar was aligned with the pan, and filled with seed. Excess seed was again scraped off with a ruler. The seed used was weighed and the volume determined. Finally, the volume of the seed used in the collar was substracted from the volume of the seed used from the previously calculated interior volume of the pan, this was the cake volume. After obtaining the volume of the cakes, the other tests were performed on the same cake.

For the texture readings one, 3.5 cm X 3.5 cm X 3.5 cm cube was cut from the center of the cake, the top 15mm was removed from each piece prior to penetration reading. The Stevens LFRA Texture Analyzer (Texture Technologies Corp. Scarsdale,N.Y) utilizes a load cell to measure the load required to maintain a constant rate of penetration to a preset depth. A 1/2 inch AOAC standard cylindrical probe was

used and penetration was at 2mm/sec speed to a depth of 6 mm.

For the moisture tests, one fourth from the center of the cake was used. The machine was calibrated thirty minutes before conducting the test (Brabender Instruments Inc. South Hackensack, NJ). Ten grams of cake was placed in aluminum pans (11.5 gms.) and dried for three hours at 155 ° C. The test was done in triplicate. Readings were recorded every ten minutes until a steady weight was maintained.

Crust and crumb color of cakes was measured using the Hunter color difference meter (Model DC-25,Labscan, Reston,Virginia).The remaining two thirds of the cake was used for color readings. A 12.7 cm X 12.7 cm 1 cm square from the crust of the cake was used for crust readings. For crumb readings a similar square was used from the white part of the cake. The instrument was calibrated with a white tile l=91.97, a=-0.80, and b=1.00. L= visual lightness, a= red(+) green(-), b= yellow(+) blue(-) and delta E is a single numerical value calculated as the square root of $l^2 + a^2 + b^2$.

Specific gravity of the batter after whipping was evaluated by using the AACC method 72-10 for specific volume.(AACC Handbook, 1983)

3.4 Cakes-Sensory Evaluation

Sensory evaluation was performed by a panel consisting of eight subjects,by the method of Quantitative Descriptive Analysis (Stone and Sidel, 1985). Training of the panelists started with a one hour language development session which allowed the panelists to evaluate, sample cakes and verbalize their perceptions. Terms were developed to describe cakes. In addition of developing terms, the subjects defined each term, to serve as a guide for panelists to minimize confusion over the meaning . Six sensory characteristics were evaluated; crust color, cell uniformity, cell size, aftertaste, cohesiveness, and crumb texture. All sensory tests were performed in booths of neutral gray color. Each panelist was provided with water to drink between samples. Three samples were tested at each session for a total of three replications over a period of four days. Samples were coded with three digit numbers picked at random, labeled and placed in white cardboard plates. A sample of the scorecard used is presented in Appendix C. The scorecard was developed using an unstructured fifteen centimeter line scale with word anchors moving from left to right with increasing intensity. The data was analyzed using SAS (SAS Institute,1982) with the general linear models procedure and the Duncan's multiple range test, at $P< 0.05$.

4.0 RESULTS AND DISCUSSION

4.1 Protein

Protein content of wheat varies from 6% to 20% depending on the relative amounts of carbohydrates and nitrogenous compounds made available to the maturing wheat. The limiting factor in protein production seems to be the amount of available nitrogen in the soil at different stages of crop development in relation to soil moisture, mineral nutrients in the soil and environmental factors that determine yield (Zeleny, 1971). Excessive rainfall usually results in low protein content, whereas dry conditions during kernel development favor high protein content (Barrmore, 1948). The variety of wheat also affects the protein content, but the differences are small compared with differences due to environmental conditions. Corrected values at 14% moisture (m.b) for grain protein and flour protein for the different treatments are presented in Table 2.

Nitrogen fertilization increases the protein content of wheat (Finney et al., 1957). This was found to be true in the results of this study. The nitrogen treatment alone significantly increased the wheat grain protein as well as flour protein. Grain protein contents of all treatments were higher than that used for the production of cake flour

TABLE 2. TOTAL NITROGEN AND PROTEIN CONTENT OF FLOUR AND PROTEIN CONTENT OF GRAIN.

TREATMENT	TOTAL NITROGEN*	FLOUR PROTEIN*	GRAIN PROTEIN*
NITROGEN	16.33[a]	11.1[a]	13.48[a]
SULFUR	15.62[b]	10.7[b]	13.22[b]
KCL	14.63[c]	10.1[c]	13.31[c]

*** Total nitrogen**=milliters, **protein**= flour protein content, expressed as % at 14% moisture basis,**grain protein**=expressed as % at 14% moisture basis. Total nitrogen, protein and in grain protein values followed by different letters in each column were significantly different when tested at $P < 0.05$.

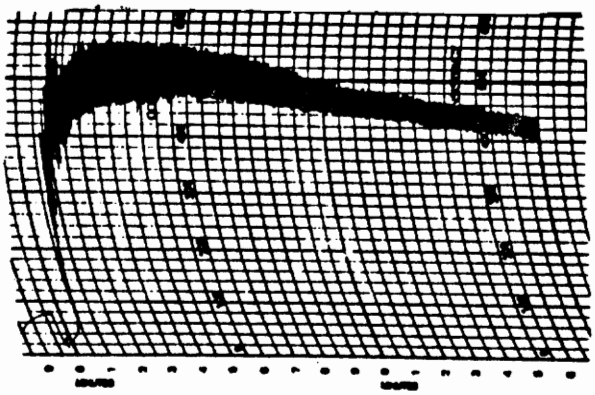
(9.0-9.5%). Sulfur, KCl and nitrogen treated grain had values characteristic of a strong wheat suitable for the production of macaroni products (>13%) and hearth bread (13-14%) (Zeleny, 1971). Significant differences for grain protein content were found among all treatments at probability < 0.05.

Comparing protein content values with those of Mansour (1982), none of the treatments had values that were characteristic of cake, cookie and cracker flours. The nitrogen, KCl and S treatments had high protein contents.

4.2 Farinograph Results

For ease of discussion, the KCl and S treated grain was also treated with urea or N but will be referred to as the KCl or S treatment. Nitrogen treatment refers to grain that was treated with nitrogen only. All treatments were performed on the grain which was milled into flour for experimentation. KCl, S, and N treatments refer to the products prepared with the flour.

The farinograph response curve reflects three important characteristics of the flour: absorption of water, dough development and dough breakdown. Farinograph response curves for soft red winter wheat (Saluda c.v.) are shown in Figure 1 and the results in Table 3. When compared to D'Appolonia's



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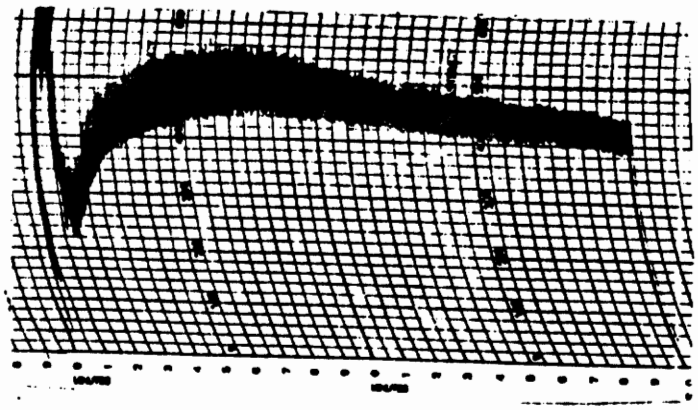
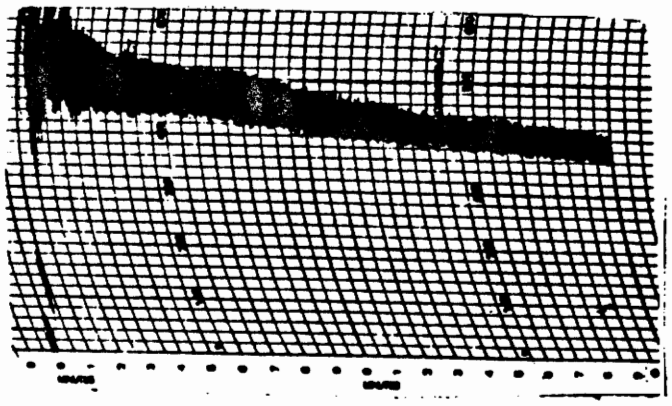


b



c

FIGURE 1. FARINOGRAPH RESPONSE CURVES

a) KCL treatment, at 63% absorption

b) Nitrogen treatment, at 62% absorption

c) Sulfur treatment, at 57% absorption

TABLE 3. RHEOLOGICAL CHARACTERISTICS OF DOUGH MEASURED BY THE FARINOGRAPH

TREATMENT	AT* (min.)	PT* (min.)	ST* (min.)	DT* (min.)	MTI* (B.U)	ABSO (%)
NITROGEN	2.88[a]	6.75[a]	11.13[a]	13.50[a]	55[a]	62[b]
SULFUR	1.0[b]	2.85[b]	9.08[a]	10.08[a]	85[b]	57[a]
KCL	2.25[a]	4.85[a]	9.50[a]	11.75[a]	60[a]	63[b]

* **AT**=arrival time,**PT**=peak time,**ST**=stability,**DT**=departure time,**MTI** =mixing tolerance index,**BU**=brabender units,**ABSO**= absorption at 14% moisture basis. Means of two replications. Farinograph values followed by different letters in each column were significantly different at $p < 0.05$.

(1984) classification of curve shapes,the three curves resembled the type III farinograph curve with medium peak time and short stability. The majority of bakery flours from hard red winter and hard red spring wheat are included in this category (D'Appolonia, 1984).

Dough characteristics are affected by several factors; variety, class of wheat, protein content of wheat and environmental conditions, as well as the grade or type of flour produced during milling. D'Appolonia (1984) compared farinograph curves from six different varieties of hard red spring wheat grown in one location. All curves were different from flours of varying protein content and water absorption.

4.21 Arrival Time

The arrival time is the measurement of the rate at which water is taken up by the dough to reach 500 Brabender units (Shuey, 1984). An extremely short arrival time indicates rapid hydration and dough formation whereas, a long arrival time indicates that water is being taken up by the various components of the flour at a slower rate (D'Appolonia and Kunerth, 1984). Differences in the degree of damaged starch and in protein quality and quantity are the most likely factors to affect rate of hydration. Arrival time increases as protein of flour increases (Markley and

Bailey, 1938). Flour from nitrogen treated grain, had the highest protein content 11.2 % (14% moisture basis) and longest arrival time at 2.88 minutes. Flour of nitrogen treated grain was significantly different from sulfur treated at probability <0.05, but not from KCl at $p>0.05$.

4.22 Peak Time and Stability Time

Peak time or dough development time for flour from nitrogen treated wheat was slower than sulfur treated and KCl treated wheat. According to Markley and Bailey (1938), increased absorption accompanies increased peak time. This was true with flours of nitrogen and KCl treatments having significantly higher peak times, as well as the highest absorption (Table 3).

Stability time gives some indication of the flour's tolerance to mixing. Flour from nitrogen treated grain was the most tolerant to mixing, which indicated a stronger dough associated with increased protein content. No significant differences were found among treatments for this variable (Table 3).

4.23 Mixing Tolerance Index, Departure Time and Absorption

Tolerance to mixing is measured by the mixing tolerance index (MTI) value or units of breakdown from the peak in five minutes. Flours with good tolerance to mixing have low

MTI's, and higher MTI values show a weaker flour (Shuey, 1984). Sulfur treated grain produced flour with the highest MTI value, demonstrating that it was a weaker flour than the other treatments. Nitrogen and KCl treated grain produced a significantly stronger flour than sulfur treatment alone at $p < 0.05$.

Departure time is the time at which the dough starts to breakdown. Longer departure times indicate stronger flours (Shuey, 1984). Nitrogen treated wheat flour had the longest departure time and was the strongest flour. However, no significant differences were found among treatments (Table 2).

Absorption represents the amount of water expressed as percent based on flour weight that is required to yield a dough or batter of predetermined consistency or viscosity (Pyler, 1973). Absorption values are shown in Table 3. Absorption is highly dependent on protein content of the flour. Merritt and Stamberg (1941) found that absorption increased by 1.5% for each 1% increase in the protein of the flour and below 9% protein there was no further decrease in absorption. Absorption values shown in Table 3, do not follow Merritt and Stamberg's findings. Flour of KCL treatment of grain had the highest readings and the protein content was next to the lowest. However, the results support D'Appolonia's (1984) studies in which no direct correlation

was seen between flour protein content and water absorption. Absorption values were significantly different from N and KCl treatments between treatments at $P < 0.05$. Starch damage is another important factor contributing to varietal and class differences in farinograph absorption (Farrand, 1969). The action of alpha amylase on damaged starch granules may lead to the release of significant amounts of bound water that will result in a decrease in consistency of the dough, thus affecting the shape of the curve.

On the basis of farinograph water absorption, peak time, and MTI, wheat flours can be classified as weak, medium, strong, and very strong (Preston and Kilborn, 1984). None of the flours exhibited weak characteristics. The peak time values for the flour of sulfur treated grain were characteristic of a medium strength flour with peak times ranging from 2.5-4.0 minutes, MTI values from 60-100, and absorptions between 54-60%. Although mixing strength is generally thought to increase as protein increases, farinograph studies have suggested the opposite (Tanaka and Tipples, 1969). The reason is not well understood, but may be related to the increased mixing required to spread the smaller amount of gluten evenly over the starch to give a continous matrix (Farrand, 1972).

The flour from KCl treated grain exhibited mixed characteristics. According to its MTI value it was medium

strength but absorption and peak times showed characteristics of a strong flour.

The flour of the nitrogen treated grain had the curve characteristics of a strong flour with peak times between 4.0 and 8.0 minutes, low MTI value 15-50, and high absorption >60%. Main uses of this flour include variety breads and hard wheat noodles. Strong wheats also are used as blending flours to increase the strength of weaker flours (Preston and Kilborn, 1984). Nitrogen flour also exhibited medium strength characteristics along with sulfur and KCl which had protein contents between 10.1-11.1%. Major uses of these flours include crackers, noodles, and low volume breads (Preston and Kilborn, 1984).

4.3 Moisture

Moisture content is one of the most important factors affecting the quality of wheat. Since the amount of dry matter in wheat is inversely related to the amount of moisture it contains, moisture content is of direct economic importance. Of even greater significance is the effect of moisture on the keeping quality of wheat. Dry sound wheat can be kept for years if properly stored, but wet wheat may spoil completely within a few days. Wheat that is too dry also has some disadvantages. Very dry wheat tends to be brittle and break easily in conventional handling

operations. Under U.S. standard for wheat that contains more than 13.5% moisture is graded "tough".

Grain moisture values in are shown in Table 4. All treatments had moisture levels below 13.5% which is considered safe for a limited period of storage. Pyler (1973) reported 14% grain moisture content to be typical for soft red winter wheat. Grain moisture contents for this experiment were much lower.

For flour moisture content a typical soft wheat flour has 12% moisture (Pyler, 1973). All treatments had higher moisture content than the standard proposed by Pyler (1973).

4.4 Ash Results

For many years the mineral (ash) content of flour has been considered an important measure of flour quality. Ash content is not related to final performance, but it gives some indication of the degree of refinement in processing (Pratt, 1971). Ash content increases with increased protein content and with flour extraction rate. Studies have shown that ash content in flour had no effect in breadmaking (Pomeranz, 1971). According to Mansour (1982) a typical cake flour has an ash content of 0.36%, and a typical cracker and cookie flour ash content of 0.40%. Values for the ash content of the experimental flours are shown in Table 4. KCL treatment had ash values characteristic of a cookie flour,

TABLE.4 MOISTURE ANALYSIS OF FLOUR AND GRAIN AND ASH, AWRC, AND PH VALUES OF THE FLOUR

TREATMENT	FLOUR MOISTURE (%)	ASH* (%)	AWRC (%)	GRAIN MOISTURE (%)	pH
NITROGEN	13.15[a]	0.35[a]	57.3[a]	12.91[a]	6.06[a]
SULFUR	12.35[a]	0.28[a]	54.8[a]	12.40[a]	6.07[a]
KCL	13.20[a]	0.41[b]	56.2[a]	12.12[a]	6.08[a]

***AWRC**=Alkaline water retention capacity, **ash** values expressed as 14% moisture basis. Moisture,ash, AWRC, grain moisture and pH values followed by different letters in each column were significantly different at $P < 0.05$.

and nitrogen treatment had ash values for a typical cake flour. The ash content of the KCl grain/flour treatment was significantly higher than the other treatments. According to the criteria established by Pratt (1971) the nitrogen treated grain made a good flour for layer cakes (0.34-0.38%) and high ratio cakes (0.30-0.36%). The flour of KCl treatment was significantly high in ash content and not suitable for cake batter, but would be suitable for the making of bread (Pomeranz, 1971).

4.5 Alkaline Water Retention Capacity

Alkaline water retention capacity test (AWRC) is one of the physiochemical tests to characterize the quality of soft wheat flours. In this method a pH approximating that of chemically leavened doughs and baked products is obtained by use of a sodium bicarbonate solution. The quantity of sodium bicarbonate absorbed by the flour is measured. Results of this test have shown to be inversely correlated with cookie spread or quality potential of the flour (Yamazaki and Donelson, 1972).

Mean values for the AWRC are presented in Table 4. According to Patterson and Allen (1981) good quality soft wheats should have low AWRC values. Quality cookie flour must have AWRC between 50-56%. Cake flours must have AWRC values between 54-62% for layer cakes, for high ratio cakes

and foam cakes between 52-56% (Pratt, 1971). The AWRC values of all flours showed good baking potential as quality soft wheat flours. No significant differences were found among samples.

4.6 pH

The pH of the flours were within the range of specifications for cookie flours 4.00-6.00 (Mansour, 1982). The flours did not follow specifications for a typical cake flour with pH of 4.7 - 4.9. No significant differences in pH were found among flours and were higher than the pH of 4.7-4.9 recommended for cake flour (Table 4.) (Mansour, 1982). This was due to the fact that none of the flours were chlorinated, a pH of 4.8 is needed for chlorinated cake flours (Gaines, 1985; Gaines and Donelson, 1985).

4.70 Cake Analysis Results- Volume

The nitrogen treated flour produced a cake with the lowest volume, due to the higher flour protein content (Table 5). Although larger cake volume is associated with soft textured wheats of low protein content, values presented in Table 5 do not support this fact (Gaines, 1985). Nitrogen fertilization of the grain and increased flour protein content have been reported in the literature to be directly related to bread loaf volume (Doekes and Wennekes, 1982). Nitrogen fertilization was found to improve

TABLE 5. SPECIFIC GRAVITY OF BATTERS AND VOLUME AND MOISTURE CONTENT OF THE CAKES

TREATMENT	VOLUME ($cm.^3$)	SPECIFIC GRAVITY	MOISTURE (%)
NITROGEN	1529.53[a]	0.7980[a]	38.84[a]
SULFUR	1737.49[b]	0.8150[a]	38.76[a]
KCL	1674.03[c]	0.7660[b]	38.79[a]

Volume, specific gravity and moisture values followed by the different letters in each column were significantly different at $P < 0.05$.

loaf volume in soft and semi hard wheats (Paredes-Lopez et al., 1985). Kosmolak and Crowle (1980) also found loaf volume of bread to increase significantly with increased flour protein content due to nitrogen fertilization. The nitrogen treatment would be a suitable flour for the making of bread. Flour of sulfur treated grain produced the cakes with the highest volume. This is reported to be related to the role of sulfhydryls and disulfides in flour baking quality (Frater, Moss and Yates, 1960). Figure 2 shows photographs of baked cakes under each treatment. The KCl and nitrogen treatments had low, dense and sunken appearances, while the cake of the sulfur treated grain retained its shape, and had a significantly higher volume.

Explanation for low volumes and sunken appearances seen for KCl and nitrogen treatments may be the lack of chlorination in the flours of all three treatments. Chlorination of cake flour gives a greater volume to cakes (Kissell, Donelson and Clements, 1979) caused by an improved batter expansion during baking (Clements and Donelson, 1982). Chlorination also alters the starch fraction of the flour (Kulp, Tsen and Daly, 1972) which allows the cake to retain its greater oven expansion and to sink less during cooling (Kissell and Yamazaki, 1979).

4.71 Specific Gravity of the Batter

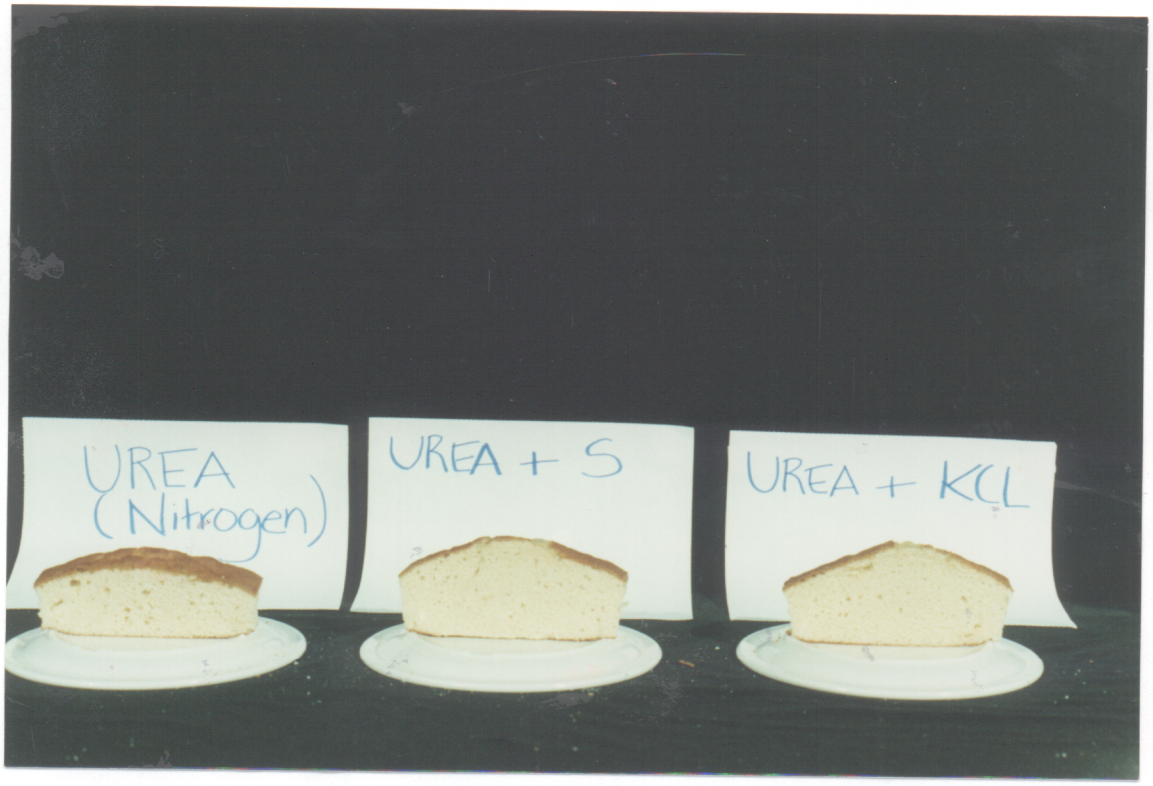


Figure.2. Color photograph of cakes made with experimental flours. Cross section, height and contour.

Specific gravity gives an indication of the amount of air incorporated into the batter. High specific gravity values for batter represent a decrease in the amount of air incorporated (Pierce and Walker, 1987). Specific gravity of batters of KCl treatment flour was found to be significantly lower than the nitrogen and sulfur treated wheat flours (Table 5.). Flour of sulfur and nitrogen had higher specific gravity values for the batter implying that less air was incorporated into the batter. This was not supported by the volume. The batter with lower specific gravity would be expected to produce the highest volume. Sulfur had the highest volume. No literature is available on the effect of treatment on specific gravity of batter.

4.72 Moisture of Crumb

The mean values for cake percent moisture as measured by the Brabender Moisture Tester are reported in Table 5. No significant differences were found among treatments for moisture readings. Any moisture differences may be due to the water absorption capacity of the flour. Water absorption is directly related to protein content. The lower protein flour binds less constitutional and interfacial water, but has more water present as bulk phase water.

4.73 Texture

The Stevens-LFRA texture analyzer was used to assess the strength of cakes. A probe was used and the depth of penetration at a definite time after loading a constant weight was recorded. Results are presented in Table 6. Cakes of nitrogen treated flour were significantly more firm than cakes of KCl and sulfur treated grain flour . According to Bourne (1982) the greater the penetration, the more tender the product. Tenderness is related to the protein content of the flour with lower protein contents produce softer cakes.(Pyler, 1973) Flour with sulfur and KCl treatments were found to be far more tender and the flour protein contents were also lower than that of nitrogen treated grain (Table 3).

4.74 Crumb and Crust Color

Mean delta E values for cake crumb and crust color as measured by the Hunter Colorimeter are reported in Table 6. The delta E values relate to the total effect of lightness and hue. The higher delta E the lighter the color. Crumb and crust color of bread was reported in the literature to be related to flour protein content (Smak, 1972). For crumb color nitrogen treated flour was found to be significantly darker in crumb color than sulfur and KCl treatments. For crust color cakes of treated flour KCl was found to be

TABLE 6. TEXTURE,CRUMB COLOR AND CRUST COLOR OF CAKES

TREATMENT	TEXTURE (gm./load)	CRUMB COLOR (delta E)	CRUST COLOR (delta E)
NITROGEN	412.17[a]	85.11[a]	46.97[a]
SULFUR	278.67[b]	84.50[b]	45.99[a]
KCL	228.30[b]	83.12[b]	42.42[b]

Texture,crumb and crust color values followed by different letters in each column were significantly different at $P < 0.05$.
Delta E= square root of $l^2 + a^2 + b^2$.

significantly darker in color than sulfur and nitrogen treatments.

4.8 Sensory Analysis

Cakes of flour from grain treated with sulfur were significantly lighter in color than cakes with nitrogen and KCl flours by the panelists. These results were in agreement with the Hunter Colorimeter results. No significant differences were seen by the panelists in texture, even though they rated nitrogen treatment cakes as being denser (Table 7). This finding was in agreement with the instrumental measurement (Table 6). No significant differences were found in cell size. Cakes of sulfur treatment had a significantly finer cell uniformity than nitrogen or KCl. Cakes of nitrogen treatment showed a more uneven cell uniformity. No significant differences were found for cohesiveness among treatments, but panelists did perceive all cakes to have a sticky mouthfeel. Cakes from unbleached flours exhibit a moister,sticky mouthfeel giving the cake a different eating quality than cakes from bleached flours (Kissell and Yamazaki, 1979). Panelists did perceive a mild aftertaste for all treatments but no significant differences were recorded among treatments. There was no treatment effect for any of the sensory properties, but the panelist effect was highly significant.

TABLE 7. SENSORY SCORES OF CAKES

TREATMENT	SENSORY PROPERTY[1] CRST.CLR*	TEXT*	CELL.S*	CELL.U*	COHE.*	AFTR.T*
	ATTRIBUTE MEANS					
NITROGEN	8.40[b]	5.88[a]	6.40[a]	7.62[a]	8.24[a]	5.15[a]
SULFUR	6.65[a]	4.40[a]	5.33[a]	5.67[b]	8.20[a]	5.69[a]
KCL	7.95[b]	5.62[a]	5.59[a]	6.82[a]	8.65[a]	4.95[a]
TREATMENT EFFECT PR>F	.0271	.3583	.7063	.0358	.9331	.5303
PANELIST EFFECT PR>F	.0001	.0001	.0001	.2989	.0002	.0544

[1]Sensory properties; scale (1-15) ,crust color (light to dark),texture (fine to coarse),cell size (small to large) cell uniformity (even to uneven), cohesiveness(less to more), aftertaste (weak to strong).
***CRUST.CLR**=crust color,**TEXT**=texture,**CELL.S**=cell size,**CELL.U**= cell uniformity, **COHE.**=cohesiveness,**AFTR.T**=aftertaste. Mean values in each column followed different letters were significantly different at $P < 0.05$.

5.0 CONCLUSIONS

In conclusion, significant differences were seen in the flour analysis results among treatments of grain, but when flours were incorporated into the baking of cakes, differences disappeared. According to farinograph curve results all three treatments behaved as hard red winter wheat and hard red spring wheat. Sulfur treated grain was found to have medium strength as a flour, while nitrogen treated grain exhibited strong strength flour characteristics. Protein contents values for all three treatments were higher than requirements for cake flours, with the nitrogen only treatment producing the flour of highest protein content. The nitrogen only treatment flour produced a cake of lowest volume and less tenderness which was in agreement with sensory panelists. This was proven true with the cake analysis results. The nitrogen and KCl treatments produced cakes of low quality; sunken in structure, dense in texture and low in volume. Flour of sulfur treatment produced cakes that maintained their structure and had the highest volume, even though the texture was dense.

Contributions of this research were as follows:

1) Significant differences were found among treatments in terms of protein content. Nitrogen treatment exhibiting a significantly higher value than KCl and

sulfur treatments.

2) All flours were medium to strong in strength, based on MTI, peak times and absorption values and did not follow characteristics for soft red winter wheat. Sulfur had characteristics of medium strength, KCl had a combination of both medium and strong strength MTI value was medium strength but absorption and peak times showed characteristics ofastrong flour. Nitrogen had characteristics of a strong flour. When incorporated into cakes the following differences were found among treatments:
    a) Nitrogen and KCl treatments produced cakes low in volume and dense in texture. Sulfur treatment of grain produced a flour that had baking properties suitable for cakes.
    b) KCl showed a lower specific gravity of the batter, and its crust and crumb color were darker, though not significantly different from S.

Further recommendations for investigation include the following;

1) Perform amino acid composition test on all treatments in order to detect differences in sulfur treated grain.

2) Compare these treatments chlorinated and non chlorinated to determine differences.
3) Evaluate the potential of the treated flours for baking of bread, as blends with other flours.
4) Quantitative and qualitative evaluation of storage proteins (glutenin and gliadin) in the grain must be considered to explain variations of quality between different treatments.

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APPENDIX A

Formulation of cakes:

Ingredients	Weight (gms.)
Flour	192
Sugar	200
Egg Whites	131.2
Egg Yolks	67.5
Shortening(Crisco)	119.8
* Whole milk(NFDM)	118.3
Baking powder	5.8
Vanilla	4.93
Salt	1.50

* Non fat dried milk (22.7 gms) was reconstituted using 240 ml distilled water. This amount was mixed, and stored in refrigerator, and used for two cakes. Fat needed to convert non fat reconstituted milk to whole milk was added as shortening and is included in shortening above (20.3 gms).

APPENDIX B

Preparation of Cakes:

Preheat oven at 375 ° F. Sift flour, baking powder and salt, through a mesh of 3 cm^3 . Combine milk and vanilla. Mix shortening five minutes at speed #4. Add sugar gradually over a 30 second time frame, continue mixing for five minutes at speed #4. Add egg yolks one at a time for 3 minutes at speed #4. Beat egg whites at speed #6 for two and a half minutes. Add 1/3 of dry ingredients (125 gms.) and beat at speed #1 for 0.5 minutes. Add 1/3 of the milk (60ml) beat at speed #3 for 0.5 minutes. Add 1/3 of the flour (125 gms.), beat at speed #1 for 0.5 minutes, then add remaining milk and beat an additional 0.5 minutes at speed #3. Finally add remaining flour (125 gms.) beat at speed #1 for 0.5 minutes. Fold egg whites into batter for 0.5 minutes at speed #1 and for 45 hand strokes. Pour 615 gms. of batter into a greased lined 8" X 8" pan. Bake for 39 minutes. Cool 15 minutes in pan,invert and cool in rack for 30 minutes.

EQUIPMENT:

General Electric Oven Model J-245

Oven watts-240v.

Oven dimensions-17" wide,15" high, 19" deep

Kitchen Aide mixer model K5SS, max. watts 300

Scale Mettler Model P1000, Scientific Products S/P

Texture Analyzer, Texture Tecnologies, Scarsdale,NJ.

Gra lab Universal Timer- Dimco Gray Co. Dayton, Ohio

Brabender Moisture tester- C/W Brabender Instruments Inc. South Hackensack, NJ.

Hunter Lab Model D25- Color and Difference Meter, Hunter Associates Laboratory, Fairfax, VA.

Farinograph. Brabender Instruments. South Hackensack, NJ.

APPENDIX C

SENSORY EVALUATION SCORECARD

Panelist #_____

CRUST COLOR:

light — dark

TEXTURE:

fine — coarse

CELL SIZE:

small — large

CELL UNIFORMITY:

even — uneven

COHESIVENESS:

less — more

AFTERTASTE:

weak — strong

VITA

Adriana Isabel Diaz Salazar was born in Tegucigalpa, Honduras on August 21, 1964 to Armando Diaz Arrivillaga and Josefina Salazar. She graduated from the American School in Tegucigalpa in May of 1982, and continued her studies in September 1982 at Virginia Polytechnic Institute and State University, in Blacksburg, Virginia. In December 1986, she received a B.S. degree in Human Nutrition and Foods (Dietetics) with plan IV of the American Dietitic Association. In Spring of 1987 she returned to Virginia Tech to pursue a masters degree in Human Nutrition and Foods. Starting in 1988, she worked as a graduate assistant at the Reference Department of Carol Newman Library, in 1988. Presently, she is a masters degree candidate.

Adriana I. Díaz S.