# PREPARATION OF HIGH TOTAL DIETARY FIBER MATERIAL FROM WHEAT MILL FEED, AND ITS UTILIZATION IN BREADMAKING

by

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# INTRODUCTION

The effect of dietary fiber in human diets on nutritional response has received increasing attention by both scientists and the general public during the last several years. There are many different types of fiber sources such as alpha-cellulose derived from woodpulp, oat bran, and wheat bran which are used in high fiber bread.

Wheat bran primarily is a source of insoluble fiber which is fairly effective in increasing fecal bulk (Schneeman 1987). Wheat bran containing 40% total dietary fiber (TDF) (Mennel milling Co. 1985) is one of the most preferable sources of fiber; however, it is relatively low in TDF.

Higher total dietary fiber materials can be extracted by chemical methods, but little work has been done on producing high fiber materials only by a grinding process. The chemical and physical properties of dietary cereal fiber can be changed by chemical agents. The functional properties of dietary fiber in the human body may vary with these changes (Rasper 1979). Therefore, one objective of our project was to develop a highly efficient method for producing wheat fiber yielding the highest TDF content, along with minimal chemical and physical changes in the fiber material. Turbo grinding and air classification techniques were used as part of the preparation procedures.

The other purpose of this work was to produce high quality fiber bread with reduced calorie content. The addition of fiber in bread-making has many negative effects on bread quality, such as low loaf volume, dense grain, and coarse texture. The optimization of fiber bread making is only possible through adjustment of formula and modification of production techniques rather than by chemical treatment of the wheat bran used in the experiment.

## LITERATURE REVIEW

### EFFECTS OF WATER ABSORPTION

Shetlar and Lyman (1944) found that doughs containing bran were very sensitive to incorrect absorption. This suggested that dough gluten could not be well-developed unless an optimum water absorption was used during the dough making process. Pomeranz, Shogren and Finney (1976) reported that water absorption increased almost linearly with added fiber. Pomeranz (1977) indicated that oat hulls reduced water absorption, whereas wheat bran and cellulose increased absorption. D'Appolonia and Young (1978) found that bran increased the farinograph absorption regardless of the source or method used for bran preparation. Absorption requirements in oat bran doughs increased with bran particle size reduction (Krishnan et al 1987). These reports and findings suggested that water absorption varied with fiber materials and their particle size.

Baking absorption of oat bran and flour blends was generally less than that of farinograph absorption ( Krishnan et al 1987 ). This might suggest that the optimum baking water absorption of bran-containing dough can not be determined by the farinograph test. Krishnan et al 1987 did not explain what caused this difference. Probably the water absorption of dough containing fiber materials can be affected by other formula ingredients ,hence different results are obtained.

EFFECTS OF MIXING TIME

Pomeranz (1977) reported that fiber materials affected both water absorption and mixing time. Lorenz (1976) found that farinograph mixing time was slightly decreased with increasing amounts of bran in the blends. Lorenz (1976) reported that replacing up to 15% of wheat flour with triticale bran or rye bran increased farinograph absorption and decreased mixing times and mixing tolerance. Krishnan et al (1987) found that oat bran blends increased dough mixing time. The contradictory results shown by these two researchers might be due to differences in fiber materials, which may have had varying effects on mixing time.

Pomeranz, Shogren and Finney (1976) reported that mixing times were increased slightly by oat hulls, increased considerably by cellulose, and were affected inconsistently by wheat bran. Based on these findings, mixing time appears to be influenced by fiber materials.

Dubois (1978) reported that dough with bran had a much longer mixing time than the control. Two stages of mixing time could produce excellent quality fiber bread. There was no detailed discussion of this effect by the author. This unique finding probably was the result of different formula and different equipment used.

Shogren, Pomeranz and Finney (1981) reported that an increase in fiber level was accompanied by an increase in mixing time. Moder et al (1984) indicated that the increase in bake mixing time with increasing percentage of whole-wheat flour was largely attributable to decreased functional protein, which created an increasing difficulty in forming a continuous phase of protein. Fiber materials have a complicated effect on dough characteristics resulting in several different physical and chemical responses during dough mixing. There is no acceptable theory to explain the effects of fiber in dough. The mechanism of dough mixing still needs to be searched further.

## EFFECTS OF BRAN

Pomeranz, Shogren and Finney (1976) reported that fibrous materials decreased loaf volume. Pomeranz (1977) reported that the large decrease in loaf volume could have resulted from either impaired gas production or gas retention. Simple pressure meter determinations of proof height readings ruled out poor gas formation. This suggested that lower loaf volume of fiber bread was caused by poor gas retention rather then gas production. Likewise, it probably indicated that there was no great effect on fermentation due to addition of fibrous materials. Poor gas retention probably can be explained by the dilution of flour protein by fiber materials and this results in a weakening of cell structure. Also, fibrous materials tend to cut gluten strands, thereby reducing gas retention power. Shetlar and Lyman (1944) reported that bran could dilute the gluten and disrupt the gluten film. This suggests that poor gas holding capacity is responsible for low loaf volume, whereas the reduction of gas retention is caused by the dilution and impairment of the gluten.

Rogers and Hoseney (1982) reported that whole wheat doughs had normal proof heights but gave only slight ovenspring during the initial baking stage. Poor gas retention appeared to be responsible for the lack of oven spring. They also indicated that the high amount of water required to hydrate bran and produce a rheologically suitable dough apparently is available for starch gelatinization. This results in doughs which set at lower temperatures thus improving oven spring could be able to increase loaf volume.

Water extracts of bran increased loaf volume (Shetlar et al 1944 and White 1913). The water soluble materials in bran which are responsible for the improvement of loaf volume was not known.

## EFFECTS OF PARTICLE SIZE

Shelter and Lyman (1944) reported that grinding the bran fiber increased loaf volume. Loaf volume of fiber breads was negatively correlated with bran size.

Prentice and D'Appolonia (1977) reported that, in ground brewer's spent grain separated into fine and coarse fractions, the finer fractions were likely to contain a higher proportion of aleurone and embryo tissue. This suggested that grinding and separating bran might cause the separation of components of bran and hence the dietary fiber content could be varied within these two fractions. Aleurone cells in bran were like holes in a sponge; when bran particle size was reduced, fewer pores and voids remained to hold water, and the water binding capacity became lower (Schaller 1978). Van Soest (1981) reported that grinding of wheat bran graduately decreased bulk volume as well as water holding capacity. The water retention, absorption, and swelling of bran might have an influence on dough absorption, mixing and even baking characteristics such as the rate of fermentation, gas retention capacity, oven spring and so on. All of these reactions could be responsible for the negative effects of fiber in dough and thus result in poor bread.

Moder et al (1984) reported that loaf volumes of breads containing finely ground white bran and shorts were somewhat higher than those of breads made with coarse white bran and shorts. This finding is the same as that of Shetlar and Lyman in 1944. On the other hand, Pomeranz et al (1977) reported that coarse and fine bran had different effects on breadmaking. The probability is that coarse bran places more strain on natural gluten of wheat flour than that of fine bran. This results in a weaker cell structure and less gas retention capacity. The water holding capacity of bran decreased with reduced particle size (Kirwan 1974 and Mongeau and Brassard 1982). These reports are quite different from that of Krishnan et al (1987) who reported that absorption requirements in oat bran doughs increased with bran particle size reduction. Mongeau and Brassard (1982) suspected that the result of destruction of capillary structure in bran was responsible for the reduction in water holding capacity.

## EFFECTS OF FERMENTATION

Pomeranz et al (1977) reported that the gas production of yeast was not impaired by added bran. Dubois (1978) indicated that doughs containing high levels of fiber aged rapidly. Pyler (1973 revised) indicated that rapid aging of dough might reduce its gas holding capacity. These reports suggest that low loaf volume of fiber bread may be caused by poor gas retention rather than by less gas production.

It is obvious that an aged dough can not make good bread. Dubois (1978) suggested that make-up procedure of breads containing added fiber was more critical than that of white breads. Probably this is because dough containing fiber is very sensitive to incorrect absorption (Shetlar and Lyman 1944) and ages rapidly during dough making.

Rogers and Hoseney (1982) found that dough rheology did not change significantly after one hour fermentation as measured by spread ratio test. Possibly the critical rheological change does not occur during the first hour of fermentation.

## EFFECTS OF SHORTENING AND SURFACTANTS

Shogren, Pomeranz and Finney (1981) reported that bread quality was improved more when shortening and surfactants were used together than when used individually. They also found that added shortening and surfactants did not overcome the detrimental effects of bran completely.

Dreese and Hoseney (1982) reported that low loaf volume and poor crumb grain could be relieved somewhat by adding surfactants and / or increasing shortening. Even if shortening can improve loaf volume, crumb grain and bread texture to some extent, still the use of shortening might not be considered desireable by some as it may increase bread calories.

Schultz and Forsythe (1967) reported that egg yolk lipoproteins may serve as surfactants to improve bread quality. Pelshenke and Hampel (1962) reported that egg yolk decreased starch retrogradation after 24 hours and produced grain with superior compressibility. The addition of egg yolk lipoprotein to formulation allowed production of acceptable breads from weaker soft wheat flour (Freilich and Frey 1941).

Egg yolk seems to be a highly effective ingredient for breadmaking. It possesses several positive effects on fiber bread, such as increased loaf volume and softer texture. However egg yolk contains high cholesterol which is undesirable, and also its high cost limits its use in bread.

## EFFECTS OF ENZYMES

Pomeranz et al (1976) found that heat-treated bran still reduced loaf volume. This indicated that enzymatic action was not related to the decrease of loaf volume.

Lorenz (1976) reported that wheat flour with bran showed decreased amylograph viscosities at all reference points. This might suggest that bran samples possess high alpha-amylase activity. He also found that fine bran caused greater changes in viscosity than coarse samples. The components of fine bran might be different from those of coarse bran.

Haseborg et al (1987) reported that loaf volume, proof time, color and flavor could be dramatically improved by different enzyme activities. However, there was no details available.

## EFFECTS OF OXIDANTS

Volpe and Lehmann (1977) reported that the volume of fiber breads with various oxidant levels differed only slightly but the break and shred and grain characteristics of the bread with 75 ppm bromate were superior to the other products. Rogers and Hoseney (1982) indicated that whole wheat doughs did not respond to $KBrO_3$ within the range of 0--50 ppm. These workers suggested that doughs with fiber need high amounts of oxidation. Probably the high water absorption of fiber dough results in weak gluten systems which negatively contributes to dough structure and gas retention. The inclusion of bromate in the formula improved loaf volume, grain and texture of oat bran breads (Krishnan et al 1987). This also showed that fiber dough required more oxidation than that of dough without fiber.

## EFFECTS OF BREAD-MAKING TECHNIQUE

Apparently the negative effects of bran addition can be overcome only through bread-making techniques. Dubois (1978) suggested that two stages of mixing and short floor time should be the right method of fiber bread-making. These two stages might be the hydration and mixing stages. Probably the addition of fiber delays gluten absorption and hence leads to two different peaks of mixing. Since dough containing fiber ages rapidly (Dubois 1978), a shorter floor time might be of help in improving bread quality.

Krishnan et al (1987) indicated that punching bran doughs resulted in excessive gas exhaustion. This implied that bran doughs should be handled with care due to their poor gas retention.

Lai, Hoseney and Davis (1987) reported that low loaf volume could be overcome by incorporating a process modification involving a " no yeast " sponge step. The authors did not discuss the details of their unique method. There are no similar approaches reported by other workers.

## EFFECTS OF BREWERS SPENT GRAIN

Prentice and D'Appolonia (1977) reported that doughs containing brewers spent grain (BSG) were more resistant to expansion and had less extensibility as measured by extensograph. Doughs with added BSG felt sticky after mixing at optimum absorption, but the doughs became normal after punching. Doughs with less than optimum absorption might feel right after mixing but had a dry appearance and gave low loaf volume (Dreese and Hoseney 1982). This indicated that BSG did affect dough rheology to a certain extent. The characteristics of doughs with BSG might be more complicated than those of doughs containing bran, since the components of BSG are quite different from those of bran. It includes yeast, and embryo residue (Pomeranz 1976). These components could lead to unusual doughs made with BSG. Added shortening and sodium stearoyl-2-lactylate increased proof height, oven spring, and dough setting (Dreese and Hoseney 1982).

# MATERIALS AND METHODS

## MATERIALS

### Ingredients

Flour : Reliance flour (11.6% protein, 13.6% moisture, 0.49% ash) was used in this study. The flour was bleached with Oxylite (benzoyl peroxide) and was not treated with either bromate or azodicarbonamide. The flour was obtained from Cargill Inc.

Bran : Bran was collected from pilot plant of Department of Grain Science and Industry at Kansas State University. Bran is a mixture of pericarp and seed coat obtained from break rolls. The bran was ground on the Hurricane Turbo Grinder then separated by Hurricane Turbo Air-separator. All bran was stored at 4 $^{0}$C.

Yeast : Red Star compressed yeast (70% moisture) obtained from Universal Foods Inc.

Yeast Food : K. C. yeast food # 207 obtained from Paniplus Company.

Gluten : Vital wheat gluten obtained from Midsol Inc..

Sugar : Sugar obtained from American Crystal sugar Co..

Brown sugar : Brown sugar obtained from American Crystal sugar Co..

Salt : Regular salt with no iodine.

**Dough Conditioners**

Ethoxylated monoglyceride (EMG) : EMG was from Breddo Food Products Corporation.

Sodium stearoyl-2-lactylate (SSL) : SSL was from U. S. Emulsifier Inc..

**Chemicals**

Potassium bromate ($KBrO_3$) : Potassium bromate was obtained from Aldrich Chemical Co..

Ascorbic acid (Vitamin C) : Ascorbic acid was obtained from Fisher Scientific Co..

Calcium propionate ($(C_3H_7COO)_2Ca$) : Calcium propionate was obtained from Kodak Chemicals Co..

**Enzymes**

Alpha-amylase (heat stable) : Alpha-amylase was purchased from Novo Biolabs Corporation.

Protease : Protease was purchased from Novo Biolabs Corporation.

Amyloglucosidase : Amyloglucosidase was purchased from Novo

Biolabs Corporation.

**Euipment**

Hurricane Turbo Grinder : This grinder was manufactured by Pillsbury Co..

Hurricane Turbo Air-sparator : The separator was manufactured by Pillsbury Co..

Balance : Mettler model P-163 was used in this study.

Scale : Scale was made by Toledo Scale Corporation.

Mixer : Mixer was manufactured by Hobart Corporation. Model A-200 was used.

Fermentation Cabinet : Fermentation Cabinet was manufactured by National Co..

Moulder : Moulder used in this study was manufactured by Moline Co..

Pan : The dimentions of pan used is listed as follow.

Interior opening : Length/Width/Depth = 10.5/4.5/2.75 inches.

Interior bottom : Length/Width = 9.875/3.625 inches.

Proof box : Proof box used was made by Anetsberger Bros. Inc..

Oven : Oven was manufactured by Reed Oven Co..

Loaf volume : Loaf volume was obtained by measuring rape-seed displacement.

**METHODS**

Heavy grinding: Turbo grinder was used in the initial part of fiber material isolation. The grinder assembly consists of a horizontal rotor formed by a series of paddle blades which are separated by discs and culminating in an ejector fan. Impact grinding takes place when the wheat bran is thrown by the rotating blades against the corrugated steel liner forming the perimeter of the grinder. Additionally, attrition grinding takes place in the vortices created behind the rotation blades. The ejector fan at the outlet end of the rotor provides horizontal air movement, drawing the stock from the inlet via each grinding compartment to the outlet. This rate of travel is controlled at the air inlet. This, in turn, controls the severity of the grind.

High Fiber Bran Isolation : A mechanical extraction of high fiber bran was adopted for the preliminary work. Bran collected from K-State pilot plant was turbo ground initially then separated with the air classifier. Two fractions were obtained after air separation. They were "coarse " and " fine " portions. Total dietary fiber (TDF) content was determined for each fraction. The coarse fraction was found to have a potential of yielding higher values of TDF. The turbo ground bran was separated with four different sets of rotor adjustments in the air classifier so as to achieve varying levels of separation. These four settings of the air classifier were abbreviated as "AA", "BB", "CC" and "DD" respectively. The product obtained from each setting was analyzed for TDF. The results indicated that the stream which was obtained from the "CC" setting possessed the highest TDF value. This stream was labelled by "CCB" in this experiment.

Total Dietary Fiber (TDF) Analysis : The determination of TDF for each sample followed AACC method 32-05 (approved on 9-25-85). The enzymes for this analysis were purchased from Novo Biolab. Corp..

Particle size analysis : The particle size analysis for coarse bran obtained from "CC" air classifier followed ASAE standardmethod ASAE S319. Tyler sieve # 16, # 20, # 32, and # 60 were used in this analysis.

Baking Test : The sponge and dough method was made by the following formula. Dough scaling weight = 539g.

Percent

| | |
|---|---|
| Flour | 100 |
| Water | variable |
| Gluten | variable |
| Yeast | 3 |
| Yeast Food | 0.7 |
| Salt | 3 |
| Sugar | 4 |
| Brown Sugar | 6 |
| "CCB" * | 20 |
| SSL | variable |
| EMG | variable |
| Potassium Bromate | variable |
| Ascorbic Acid | variable |
| Calcium Propionate | 0.4 |

* Coarse coarse bran

The dough-making conditions were as follows :

| | Time | Temp.($^{0}C$) |
|---|---|---|
| Mixing time | variable | |
| Dough temp. | | 25-26.6 |
| Fermentation time | variable | 29.4, 85% humidity |
| Floor time | variable | room temperature |
| Proof time | 55-65 min. | 40.6, 95% humidity |
| Bake | 23 min. | 218.3 |

Statistical analysis : There were two analytical methods used inthis work. One was split plot design which was used to analyse data of fiber material isolation by means of turbo grinding and air classification. Data obtained from a screening experiment including modification of bread formula and improvement of dough preparation was analysed by analysis of variance method. The other was response surface methodology (RSM) (Box et al 1978) which was used to optimize fiber-bread-making.

# RESULTS AND DISCUSSIONS

## PREPARATION OF HIGH FIBER MATERIAL FROM WHEAT MILL FEED

Attempts to isolate the highest total dietary fiber (TDF) from wheat was first directed to wheat mill feed, non-flour milling fractions such as bran, shorts, red-dog and the combination of these three portions--feed. Fig. 1 indicates the procedure for the preparation of high fiber material.

All these four fractions of wheat mill feed were processed separately, first with turbo grinding then air classification so as to separate the coarse fraction from the fine one. The TDF content for each fraction of wheat mill feed is shown in Table I. The results indicate that the original bran collected from the break rolls had 50.7% TDF. However, this bran gave a lower TDF, only 47.84%, after turbo grinding. Probably the decrease of TDF was caused by the mechanical action during turbo milling.

Each product after turbo grinding was separated into coarse and fine portions by the air classifier. The average particle size of coarse fraction was about 375 microns and mean particle size for fine fraction was around 14 microns (Table IV). The coarse fraction of bran contained higher TDF, 50.5%, which was nearly the same as the original bran,

Fig. 1. Flow chart of the isolation of high fiber material from wheat.

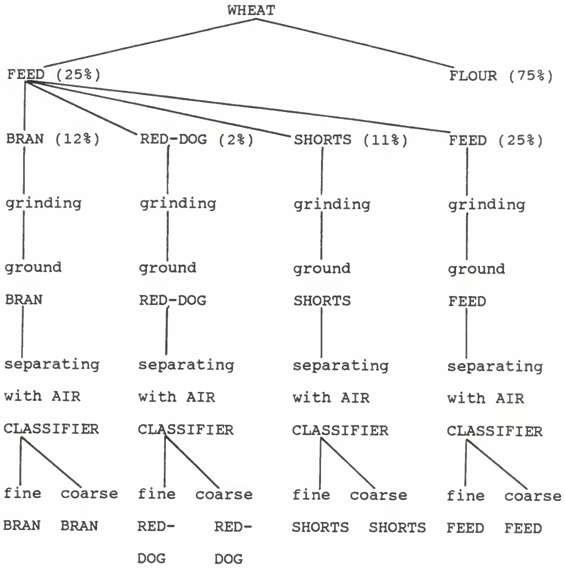

WHEAT
FEED (25%)
FLOUR (75%)
BRAN (12%)
RED-DOG (2%)
SHORTS (11%)
FEED (25%)
grinding
grinding
grinding
grinding
ground BRAN
ground RED-DOG
ground SHORTS
ground FEED
separating with AIR CLASSIFIER
separating with AIR CLASSIFIER
separating with AIR CLASSIFIER
separating with AIR CLASSIFIER
fine BRAN
coarse BRAN
fine RED-DOG
coarse RED-DOG
fine SHORTS
coarse SHORTS
fine FEED
coarse FEED

Table I Notes:

* * Numbers are the average of 2 observations.
* *1 Samples obtained after turbo mill.
* *2 Samples obtained after turbo mill and air classification (Coarse fraction).
* *3 Samples obtained after turbo mill and air classification (Fine fraction).

Table I. Total Dietary Fiber Content of Samples.

| Sample | TDF* (%) |
|---|---|
| Bran | 50.68 |
| Bran T.M.*1 | 47.84 |
| Coarse bran*2 | 50.52 |
| Fine bran*3 | 33.59 |
| Shorts | 35.99 |
| Shorts T.M.*1 | 35.41 |
| Coarse shorts*2 | 40.19 |
| Fine shorts*3 | 26.23 |
| Red-dog | 30.47 |
| Red-dog T.M.*1 | 33.85 |
| Coarse red-dog*2 | 32.04 |
| Fine red-dog*3 | 24.67 |
| Feed | 43.80 |
| Feed T.M.*1 | 37.38 |
| Coarse feed*2 | 46.28 |
| Fine feed*3 | 31.05 |

whereas the fine fraction gave a much lower TDF than did the coarse one (Fig. 2). The non-TDF residues might be readily susceptible to mechanical action when they were subjected to turbo grinding so that they were broken into much smaller pieces or particles with lower density. Perhaps the structure among non-TDF residues was weaker than that of fiber residues and thus fine fraction contained more non-TDF residues.

The same procedure was also used on shorts. We found the coarse shorts to contain the highest TDF, 40.19%, and the fine fraction, which was obtained through turbo grinding and air classification, to possess the lowest TDF value 26.23% (Table I). We applied the same study to red-dog and feed, and had very similar results. The fine fraction of feed yielded a very low TDF content, 31.05%.

Bran, shorts, red-dog, and feed contained significantly different amount ($p=0.001$) of TDF (Table II). Bran had the highest TDF among these four materials (Table II). Turbo grinding did not change the amount ($p=0.19$) of TDF. However, a very significantly different amount of TDF ($p=0.0001$) was obtained through air classification (Table II). According to the results of Table II, air classification provides a highly efficient means for separation of high TDF material. To isolate the highest TDF material from wheat mill feed we have to start from wheat

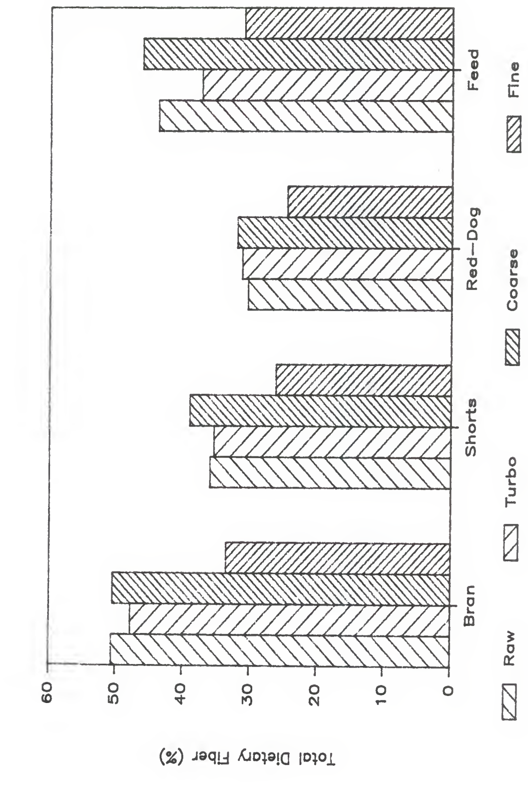
Fig. 2. Total dietary fiber of bran, shorts, red-dog and feed.

Raw--regular bran, shorts, red-dog and feed without processing.

Turbo--bran, shorts, red-dog and feed ground by turbo mill.

Coarse--coarse fraction of bran, shorts, red-dog and feed collected from regular bran, shorts, red-dog and feed respectively which were first ground by turbo mill then separated by air classifier.

Fine--fine fraction of bran, shorts, red-dog and feed collected from regular bran, shorts, red-dog and feed respectively which were first ground by turbo mill then separated by air classifier.



Total Dietary Fiber (%)
0
10
20
30
40
50
60
Bran
Shorts
Red-Dog
Feed
Raw
Turbo
Coarse
Fine

Table II. Statistical Results for Table I.

| Sample | TDF* (%) | |
|---|---|---|
| Bran | 45.66 | a |
| Feed | 39.63 | b |
| Shorts | 34.45 | c |
| Red-dog | 30.26 | d |
| **Turbo Grinding** | **TDF* (%)** | |
| Non-turbo | 40.23 | e |
| Turbo | 36.58 | e |
| **Air Classifier** | **TDF* (%)** | |
| Coarse | 42.25 | f |
| Non-air | 39.43 | g |
| Fine | 28.88 | h |

* Numbers are the average of 2 observations.

Level of significance = 5%.

Means with the same letter are not significantly different.

bran, based on the results shown in Table I and Table II. To achieve this goal, four sets of separation systems were designed for the air classifier. These were "AA", "BB", "CC" and "DD" settings. These four sets of air classifier settings were modified through the change of rotor settings and louver by which different separations could be obtained.

Wheat bran was ground on the turbo mill and separated through all four settings of the air classifier. The TDF value of streams collected from each setting is listed in Table III. Fig. 3 lists the TDF content of bran and feed after AA, BB, CC and DD settings of the air classifier.

Coarse bran from setting CC shows the highest amount of TDF content, up to 60.8% (Table III). We expected that the TDF content would have been increased with the variation in setting from the first to fourth; however, there was no significant different in TDF content between setting CC and DD (Table III). This implied that the setting CC provided almost the same capacity of separation for ground bran as setting DD, in terms of nondigestable components. Some properties of high fiber bran obtained from "CC" setting are listed in Table IV.

HIGH FIBER BREAD MAKING----ONE VARIABLE AT A TIME APPROACH

Table III. Total Dietary Fiber Content of Samples Turbo Milled and Air Classified with "AA", "BB", "CC", "DD" Settings.

| Sample | TDF* (%) | |
|---|---|---|
| Coarse bran "AA" | 51.44 | c, d |
| Coarse feed "AA" | 46.97 | d, e, f |
| Coarse bran "BB" | 53.03 | b, c |
| Coarse feed "BB" | 48.54 | c, d, e |
| Coarse bran "CC" | 60.80 | a |
| Coarse feed "CC" | 56.53 | a, b |
| Coarse bran "DD" | 58.98 | a |
| Coarse feed "DD" | 46.94 | d, e, f |

* Numbers are the average of 2 observations.

Level of significance = 5%.

Means with the same letter are not significantly different.

Fig. 3. Total dietary fiber of bran and feed ground on the turbo mill then separated by AA, BB, CC and DD classifier settings.

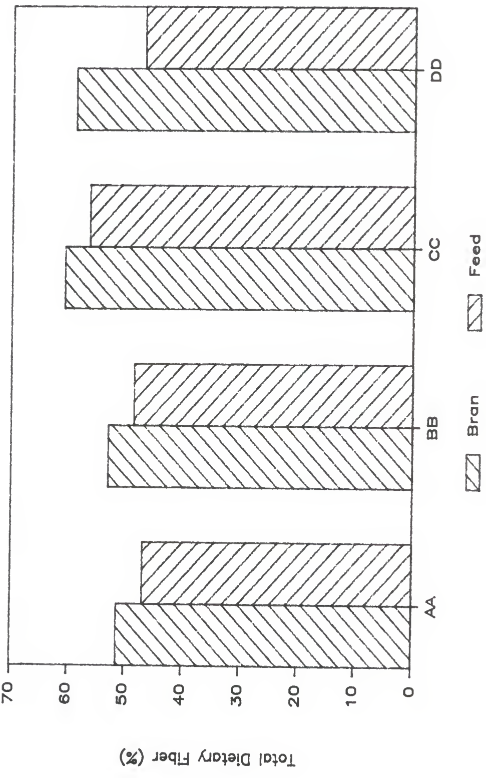

Total Dietary Fiber (%)
70
60
50
40
30
20
10
0
AA
BB
CC
DD
Bran
Feed

Table IV. Properties and Particle size of Coarse Bran Obtained from Setting "CC" Air Classification.

| Properties | % db | |
|---|---|---|
| Moisture | 6.67 | |
| Protein (N x 5.7) | 14.80 | |
| Fat | 2.98 | |
| Ash | 7.31 | |
| Average particle size | 375 | microns |
| Surface area | 491.5 | ($cm^2$) / g |
| Particle number | 103852 | particles / g |

Baking tests conducted with formula (A) (Table V) and conditions (A) (Table VI) showed that doughs with 90% absorption and 6 minute mixing gave the highest loaf volume (Table VII and Fig. 4). However, doughs with 90% absorption were stiff, dry and could not be readily sheeted out. Doughs were elastic and not sufficiently extensible. This might be due to under mixing and/or inadequate absorption. Doughs became less stiff after fermentation. Doughs with higher absorption, exceeding 90%, yield bread with lower volume. Doughs containing 105% absorption were quite tender but manageable. There was no significant effect ($p=0.08$) exerted by water absorption on loaf volume in this experiment. Proof time decreased as the absorption increased (Table VIII and Fig. 5). Water absorption did have a significant effect ($p=0.004$) on proof time. This might indicate that doughs containing higher amounts of water possessed greater extensibility and thus could be readily expanded by gas diffusion during proofing. Based on this, we would suspect that doughs with higher absorption should have given better loaf volume, whereas, they gave lower loaf volume than those of breads made with 90% absorption. This was probably because high absorption doughs lost their gas retention capacity to some extent when they were heated in the oven. An acceptable bread grain but with dense texture was obtained from 90% absorption doughs. At this stage, it

Table V. Bread Formulation (A).

| Ingredients | Amount (%) |
|---|---|
| Flour*1 | 100.0 |
| Water | Variable |
| Vital wheat gluten | 10.0 |
| Yeast*2 | 3.0 |
| Yeast food*3 | 0.7 |
| Salt | 3.0 |
| Sugar | 4.0 |
| Brown sugar | 6.0 |
| Wheat bran*4 | 20.0 |
| SSL | 0.3 |
| EMG | 0.5 |
| Calcium propionate | 0.4 |

*1 Cargill, 11.6% protein.

*2 Compressed yeast.

*3 Bromate type.

*4 Coarse bran collected from "CC" setting air classifier.

Table VI. Dough Processing Conditions (A).

| Process | Time | Temp. (C) | Conditions |
|---|---|---|---|
| Mixing time | 6 min | | |
| Dough temp. | | 25.6-26.7 | |
| Fermentation | 3.5 hr | 29.4 | 85% humidity |
| Floor time | 20 min | | |
| Punch | | | heavy |
| Moulding | | | light pressure on pressure board |
| Proof* | 55-65 min | 40.6 | 95% humidity |
| Bake | 23 min | 218.3 | |

* Proof heigtht = 2.5 cm above pan edge.

Table VII. Effect of Water Absorption on Loaf Volume of Fiber-bread with 6 min Mixing Time.

| Water absorption (%) | Loaf volume* (cc) | Standard deviation | Crumb grain |
|---|---|---|---|
| 80 | 2617 b | 52 | poor |
| 90 | 2725 a | 43 | fair |
| 95 | 2642 a, b | 38 | fair |
| 100 | 2617 b | 38 | poor |
| 105 | 2608 b | 58 | poor |

* Numbers are averages of 3 independent observations.

Level of significance = 5%.

LSD = 89.43

Means with the same letter are not significantly different.

Fig. 4 Effect of water absorption on loaf volume.

Doughs made with formulation (A), dough processing (A) and 6 minute mixng time.

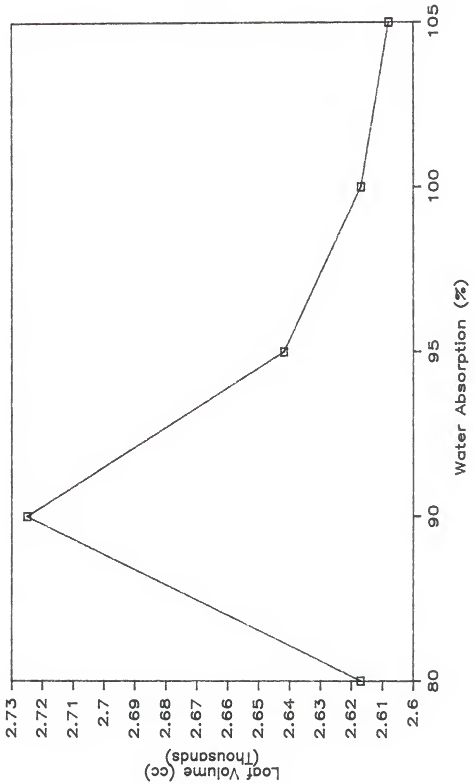

Loaf Volume (cc)
(Thousands)
2.73
2.72
2.71
2.7
2.69
2.68
2.67
2.66
2.65
2.64
2.63
2.62
2.61
2.6
80
90
95
100
105
Water Absorption (%)

Table VIII. Proof Time of Doughs with Various Absorptions.

| Water absorption (%) | Proof time* (min) | Standard deviation |
|---|---|---|
| 80 | 71 a | 2 |
| 90 | 65 b | 2.6 |
| 95 | 63 b | 2 |
| 100 | 63 b | 2.6 |
| 105 | 61 b | 2.6 |

Note: Mixing time = 6 min.

* Proof height = 2.5 cm above pan edge.

Numbers are averages of 3 independent observations.

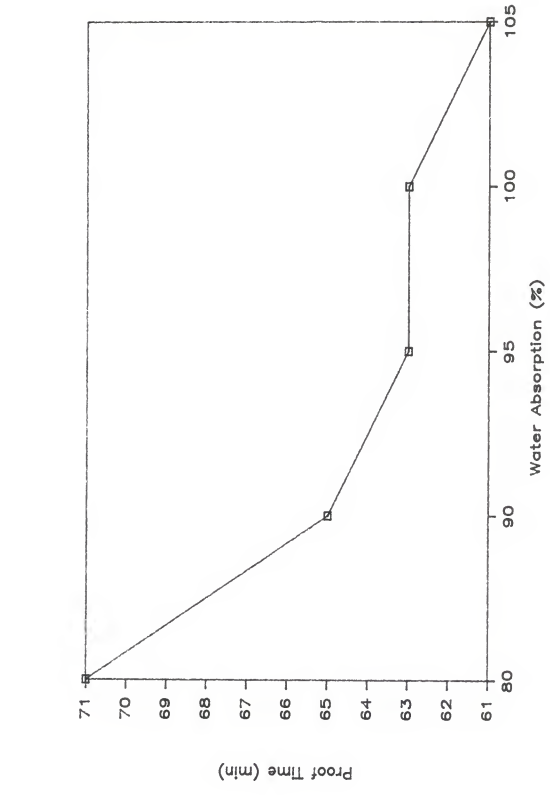
Level of significance = 5%.

LSD = 4.38

Means with the same letter are not significantly different.

Fig. 5. Effect of water absorption on proof time.

Doughs made with formulation (A), dough processing (A) and 6 minute mixing time.


Proof Time (min)
71
70
69
68
67
66
65
64
63
62
61
80
90
95
100
105
Water Absorption (%)

appeared that doughs with 90% absorption and 6 minute mixing yielded the best loaf (Table VII and IX) although the crumb grain was only fair. Mixing time had a highly significant influence (p=0.0001) on loaf volume in this experiment. Based on these results it was concluded that wheat bran would decrease mixing time.

High fiber doughs appear to be sensitive to mixing time (Fig. 6) and absorption (Fig. 4). The hydration of wheat gluten could be affected by added bran, which might bind or release water during or after mixing. Therefore, the water distribution in a bran dough system could be altered. This phenomenum might exert a negative effect on development of gluten, thereby leading to a poor gas holding capacity.

If gas production power was responsible for the poor loaf volume, longer fermentation should have improved bread volume. Nevertheless, shorter fermentation gave better volume (Table X and Fig 7). Fermentation time did have a significant effect (p=0.006) on loaf volume. This might suggest that the poor volume is caused by less gas retention rather than gas production. Possibly bran caused doughs to mature rapidly and hence resulted in an over-aged condition. An old dough gives poor gas retention while a young dough gives an inferior loaf (Pyler 1973). The optimum fermentation level of bran doughs might be less than that of white flour doughs.

Table IX. Effect of Mixing Time on Loaf Volume of Fiber-bread with 90% Water Absorption.

| Mixing time (min) | Loaf volume* (cc) | Standard deviation | Crumb grain |
|---|---|---|---|
| 4 | 2567 b | 52 | poor |
| 5 | 2707 a | 38 | fair |
| 6 | 2733 a | 38 | fair |
| 7 | 2667 a | 58 | poor |
| 8 | 2525 b, c | 43 | poor |
| 9 | 2450 c | 43 | poor |

Note: * Numbers are averages of 3 independent observations.

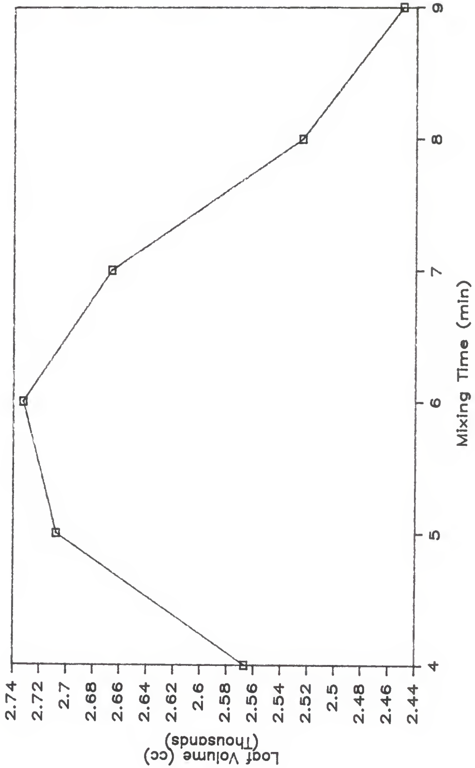
Level of significance = 5%.

LSD = 81.83

Means with the same letter are not significantly different.

Fig. 6 Effect of mixing time on loaf volume.

Doughs made with formulation (A), dough processing (A) and 90% water absorption.



Loaf Volume (cc)
(Thousands)
2.74
2.72
2.7
2.68
2.66
2.64
2.62
2.6
2.58
2.56
2.54
2.52
2.5
2.48
2.46
2.44
4
5
6
7
8
9
Mixing Time (min)

Table X. Effect of Fermentation on Loaf Volume of Fiber-bread.

| Fermentation time (hr) | Loaf volume* (cc) | Standard deviation | Crumb grain |
|---|---|---|---|
| 2 | 2550 b | 43 | poor |
| 2.5 | 2692 a | 52 | fair |
| 3.5 | 2733 a | 38 | fair |
| 4 | 2675 a | 50 | poor |

Note: Water absorption = 90%.

Mixing time = 6 min.

* Numbers are averages of 3 independent observations.

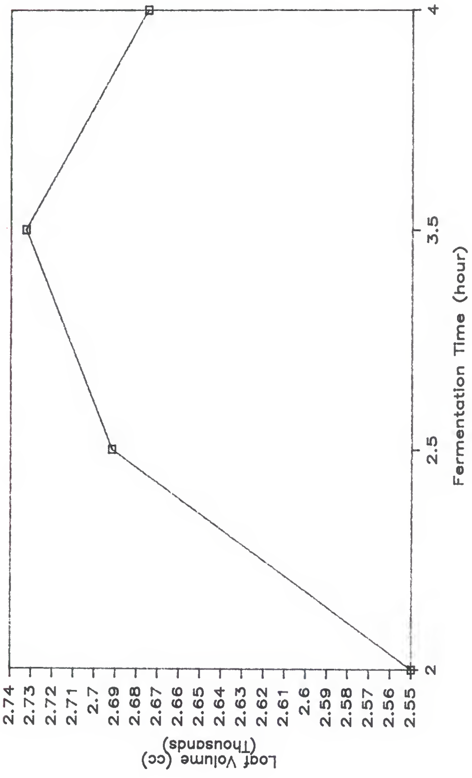
Level of significance = 5%.

LSD = 87.01

Means with the same letter are not significantly different.

Fig. 7 Effect of fermentation time on loaf volume.

Doughs made with formulation (A), dough processing (A), 90% water absorption and 6 minute mixing time.


Loaf Volume (cc)
(Thousands)
2.74
2.73
2.72
2.71
2.7
2.69
2.68
2.67
2.66
2.65
2.64
2.63
2.62
2.61
2.6
2.59
2.58
2.57
2.56
2.55
2
2.5
3.5
4
Fermentation Time (hour)

## BREAD MADE WITH FORMULATION (B)

Formulation (B) (Table XI) contained less wheat gluten, increased surfactants, and included oxidants, compared to formula (A) while the dough making condition was the same as formula (A). Breads made with formulation (B) gave lower volume (Table XII). Oxidants were used to strengthen doughs made with 105% absorption and 8% gluten. The purpose of decreasing gluten was to cut down production costs. Doughs made with 9 minute mixing (Table XII and Fig. 8) had better volume, but were still lower than that of breads baked with formulation (A) (Table V). In this experiment mixing time had no significant influence (p=0.06) on loaf volume. Oxidants improved mixing tolerance. Doughs with oxidants were dryer and easier to handle even if they were made with a level of 105% absorption. Doughs containing oxidants exhibited better handling characteristics when they were subjected to mechanical processing.

## BAKING BREAD WITH 115% WATER ABSORPTION AND VARIOUS MIXING TIMES

Doughs made with 115% absorption had a soft crumb and good grain (Table XIII). The optimum mixing amount for 115%

Table XI. Bread Formulation (B).

| Ingredients | Amount (%) |
|---|---|
| Flour | 100.0 |
| Water | Variable |
| Vital wheat gluten | 8.0 |
| Yeast | 3.0 |
| Yeast food | 0.7 |
| Salt | 3.0 |
| Sugar | 4.0 |
| Brown sugar | 6.0 |
| Wheat bran (coarse) | 20.0 |
| SSL | 0.5 |
| EMG | 0.7 |
| Calcium propionate | 0.4 |
| Ascorbic acid | 0.02 |
| Potassium bromate | 0.0015 |

Table XII. Effect of Mixing Time on Loaf Volume of Fiber-bread with 105% Water Absorption.

| Mixing time (min) | Loaf volume* (cc) | Standard deviation | Crumb grain |
|---|---|---|---|
| 7 | 2550 b | 43 | poor |
| 8 | 2583 a, b | 38 | poor |
| 9 | 2642 a | 38 | fair |
| 10 | 2575 a, b | 43 | fair |
| 11 | 2550 b | 43 | good |
| 12 | 2525 b | 43 | good |

Note: * Numbers are averages of 3 independent observations.

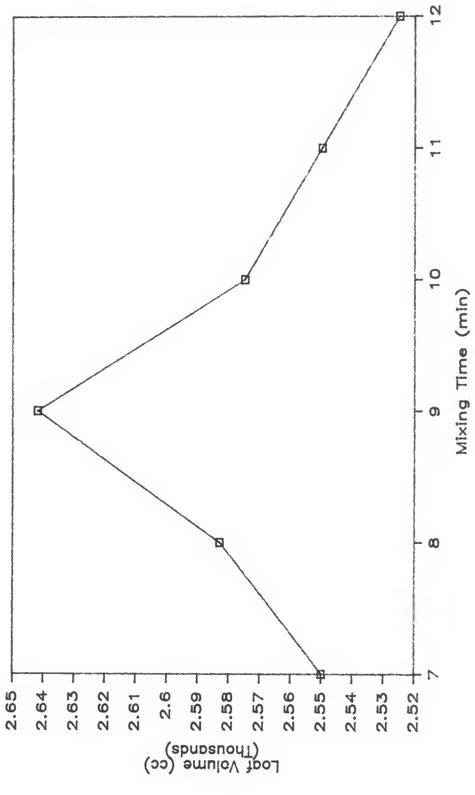
Level of significance = 5%.

LSD = 74.13

Means with the same letter are not significantly different.

Fig. 8 Effect of mixing time on loaf volume.

Doughs made with formulation (B), dough processing (A) and 105% water absorption.



Loaf Volume (cc)
(Thousands)
2.65
2.64
2.63
2.62
2.61
2.6
2.59
2.58
2.57
2.56
2.55
2.54
2.53
2.52
7
8
9
10
11
12
Mixing Time (min)

Table XIII. Effect of Mixing Time on Loaf Volume of Fiber-bread with 115% Water Absorption.

| Mixing time (min) | Loaf volume* (cc) | | Standard deviation | Crumb Grain |
|---|---|---|---|---|
| 9 | 2683 | b, c | 38 | fair |
| 10 | 2700 | a, b, c | 50 | good |
| 11 | 2750 | a, b | 43 | good |
| 12 | 2775 | a | 43 | good |
| 13 | 2642 | c | 38 | poor |
| 14 | 2542 | d | 52 | poor |
| 15 | 2517 | d | 38 | poor |

Note: Fermentation time = 3.5 hrs.

* Numbers are averages of 3 independent observations.

Level of significance = 5%.

LSD = 76.43

Means with the same letter are not significantly different.

absorption doughs was studied. The 12 min mixing gave the best loaf volume while mixing with 13 minutes had less volume (Table XIII and Fig. 9). At 115% absorption there was a highly significant effect (p=0.0001) exerted by mixing time on loaf volume. It appears that the effect of mixing time on loaf volume varies with different levels of absorption, perhaps indicating an interaction between mixing time and water absorption. High absorption required larger amounts of oxidation (Table XIV). Table XIV shows high oxidants did improve loaf volume and crumb grain. Data (p=0.02) showed oxidants had a significant influence on bread volume.

Emulsifiers such as SSL and EMG had a greater improvement on loaf volume than did shortening (Table XV). Even breads made with 3% of shortening had a volume of 2625 cc, while, breads made with 0.5% SSL and 0.7% EMG yielded 2742 cc (Table XV). There was not much difference in bread volume between 2% shortening and 3% shortening (Table XV). Shortening had a significant effect (p=0.001) on loaf volume. It is not desirable to use shortening beyond 3% in low calorie bread-making.

BREAD BAKED WITH FORMULATION (C) AND DOUGH PROCESSING (B)

We suspected wheat bran might age dough rapidly. Thus,

Fig. 9 Effect of mixing time on loaf volume.

Doughs made with formulation (B), dough processing (A) and 115% water absorption.

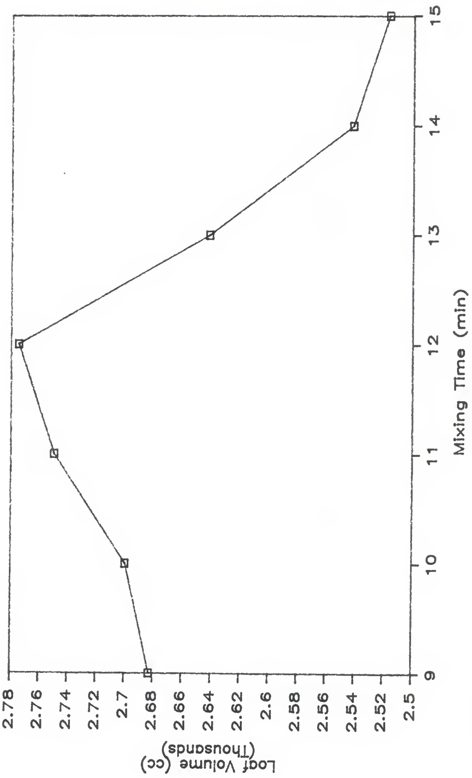

Loaf Volume (cc)
(Thousands)
2.78
2.76
2.74
2.72
2.7
2.68
2.66
2.64
2.62
2.6
2.58
2.56
2.54
2.52
2.5
9
10
11
12
13
14
15
Mixing Time (min)

Table XIV. Effect of Potassium Bromate on Loaf Volume of Fiber-bread with 115% Water Absorption.

| Oxidants | Amount (ppm) | Loaf volume* (cc) | Standard deviation | Crumb grain |
|---|---|---|---|---|
| Potassium Bromate | 0 | 2617 b | 38 | poor |
| Potassium Bromate | 5 | 2675 a, b | 43 | fair |
| Potassium Bromate | 10 | 2733 a | 52 | fair |
| Potassium Bromate | 15 | 2742 a | 38 | good |

Note: Mixing time = 12 min.

* Numbers are averages of 3 independent observations.

Level of significance = 5%.

LSD = 81.53

Means with the same letter are not significantly different.

Table XV. Effect of Shortening or Surfactants on Loaf Volume.

| Shortening or Surfactants | Amount (%) | Loaf volume* (cc) | Standard deviation | Crumb grain |
|---|---|---|---|---|
| Shortening | 1 | 2517 c | 38 | poor |
| Shortening | 2 | 2617 b | 52 | fair |
| Shortening | 3 | 2625 b | 43 | fair |
| SSL + EMG | 0.5 + 0.7 | 2742 a | 38 | good |

Note: Water absorption = 115%.

Mixing time = 12 min.

* Numbers are averages of 3 independent observations.

Level of significance = 5%.

LSD = 81.53

Means with the same letter are not significantly different.

reducing fermentation and cutting down floor time might be expected to overcome negative effects of wheat bran. Therefore, dough processing conditions were modified. Fermentation time was reduced to 2.5 hours since this would still give good volume (Table X). Doughs did not tear during moulding with 10 min of floor time. In order to shorten the proof time, dough temperature was raised to 27.8 $^{0}C$.

Breads made with formulation (C) (Table XVI) and processing (B) (Table XVII) gave very good loaf volume (Table XVIII and Fig. 10) and crumb grain. In this experiment mixing time had a highly significant effect ($p=0.0006$) on loaf volume. These results suggest that a very good loaf of high fiber bread can be made if doughs are processed appropriately. Characteristics of doughs containing high fiber materials are quite different from those of white bread doughs. Baking a good fiber bread through the modification of baking technique was our objective.

## OPTIMIZATION OF HIGH FIBER BREAD MAKING----RESPONSE SURFACE METHOD (RSM)

A response surface design was used to optimize high fiber bread-making. Water absorption, mixing time,

Table XVI. Bread Formulation (C).

| Ingredients | Amount (%) |
|---|---|
| Flour | 100.0 |
| Water | 116.0 |
| Vital wheat gluten | 10.0 |
| Yeast | 3.0 |
| Yeast food | 0.7 |
| Salt | 3.0 |
| Sugar | 4.0 |
| Brown sugar | 6.0 |
| Wheat bran (coarse) | 20.0 |
| SSL | 0.5 |
| EMG | 0.7 |
| Calcium propionate | 0.4 |
| Ascorbic acid | 0.02 |
| Potassium bromate | 0.0015 |

Table XVII. Dough Processing Conditions (B).

| Process | Time | Temp. (C) | Conditions |
|---|---|---|---|
| Mixing time | variable | | |
| Dough temp. | | 27.8-28.9 | |
| Fermentation | 2.5 hr. | 29.4 | 85% humidity |
| Floor time | 10 min | | |
| Punch | | | moderate |
| Moulding | | | light pressure on pressure board |
| Proof* | 55-65 min. | 40.6 | 95% humidity |
| Bake | 23 min. | 218.3 | |

* Proof height = 2.5 cm above the pan edge.

Table XVIII. Effect of Mixing Time on Loaf Volume of Fiber-bread made with Formulation (C) and Dough Processing (B).

| Mixing time (min) | Loaf volume* (cc) | Standard deviation | Crumb grain |
|---|---|---|---|
| 11 | 2892 b | 52 | good |
| 12 | 3008 a | 52 | good |
| 13 | 2933 a, b | 58 | good |
| 18 | 2717 c | 38 | fair |

* Numbers are averages of 3 independent observations.

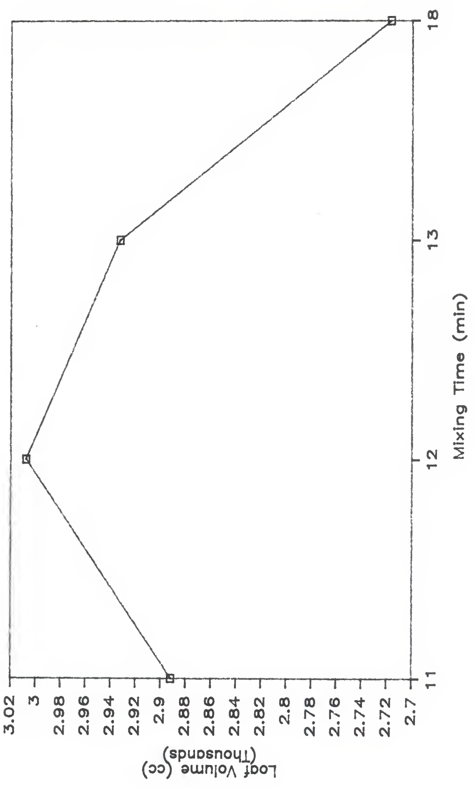
Level of signigicance = 5%.

LSD = 95.12

Means with the same letter are not significantly different.

Fig. 10  Effect of mixing time on loaf volume.

Doughs prepared with formulation (C),
dough processing (B) and 116% water absorption.


Loaf Volume (cc)
(Thousands)
3.02
3
2.98
2.96
2.94
2.92
2.9
2.88
2.86
2.84
2.82
2.8
2.78
2.76
2.74
2.72
2.7
11
12
13
18
Mixing Time (min)

fermentation time, and floor time were four variables selected for study, in terms of effect on bread volume and quality. Any interaction among these four variables were also of interest and could be detected by means of response surface methodology. The range of each variable was easily set through screening experiments--one variable at a time method. Table XIX shows the range examined for each variable. Bread formula (C) and dough-making condition (B) were kept the same, except for these four variables. The RSM design called for 31 runs and included 7 runs at the center point of the experiment (Table XX).

In order to ascertain any significant effect on bread loaf volume or quality due to these four variables, we employed a stepwise procedure to fit the model. The judgement of the effect of each variable on bread volume or quality was based on 95% level of significance. The results indicated that water absorption ($p=0.05$), mixing time ($p=0.02$), and fermentation time ($p=0.03$) had a significant effect on bread volume; however, there was no significant influence exerted by floor time ($p=0.26$) on bread volume. The interaction between water absorption and fermentation time ($p=0.07$) had no significant effect on bread volume. Water absorption ($p=0.0001$), mixing time ($p=0.005$) and fermentation time ($p=0.003$) showed a highly significant influence on bread quality, while floor time ($p=0.01$) as

Table XIX. The Range of Four Variables Observed.

| Variables | |
|---|---|
| Water absorption, % | 85-117 |
| Mixing time, min | 6-16 |
| Fermentation, hr | 1.5-3.5 |
| Floor time, min | 8-20 |

Table XX Notes:

*1 Average of 3 dependent observations.

*2 The grading points was obtained by the average of 6 aspects. They are crust color, break and shred, symmetry, grain, crumb color, and texture.

Score range is from 0 to 10. Scores shown in this table are also the average of 3 dependent observations.

*3 # denotes different working days.

Table XX. The Thirty One Dough-making Combinations Designed by Response Surface Method (RSM).

| Dough # | Floor (min) | MT. (min) | WABS. (%) | FER. (hr) | Vol*1 (cc) | Quality*2 | Day # |
|---|---|---|---|---|---|---|---|
| 1 | 8 | 11.0 | 101 | 2.5 | 2763 | 6.63 | 4 |
| 2 | 11 | 8.5 | 93 | 2.0 | 2450 | 3.01 | 5 |
| 3 | 11 | 8.5 | 93 | 3.0 | 2550 | 3.58 | 2 |
| 4 | 11 | 8.5 | 109 | 2.0 | 2925 | 7.13 | 5 |
| 5 | 11 | 8.5 | 109 | 3.0 | 2938 | 7.46 | 5 |
| 6 | 11 | 13.5 | 93 | 2.0 | 2475 | 2.58 | 2 |
| 7 | 11 | 13.5 | 93 | 3.0 | 2475 | 4.55 | 2 |
| 8 | 11 | 13.5 | 109 | 2.0 | 2863 | 7.63 | 5 |
| 9 | 11 | 13.5 | 109 | 3.0 | 2725 | 6.46 | 1 |
| 10 | 14 | 6.0 | 101 | 2.5 | 2625 | 4.38 | 5 |
| 11 | 14 | 11.0 | 85 | 2.5 | 2425 | 2.75 | 1 |
| 12 | 14 | 11.0 | 101 | 1.5 | 2650 | 3.82 | 1 |
| 13 | 14 | 11.0 | 101 | 2.5 | 2744 | 5.92 | 2 |
| 14 | 14 | 11.0 | 101 | 2.5 | 2756 | 6.08 | 3 |
| 15 | 14 | 11.0 | 101 | 2.5 | 2781 | 5.71 | 3 |
| 16 | 14 | 11.0 | 101 | 2.5 | 2725 | 5.50 | 3 |
| 17 | 14 | 11.0 | 101 | 2.5 | 2800 | 6.42 | 4 |
| 18 | 14 | 11.0 | 101 | 2.5 | 2763 | 6.33 | 4 |
| 19 | 14 | 11.0 | 101 | 2.5 | 2875 | 6.42 | 5 |
| 20 | 14 | 11.0 | 101 | 3.5 | 2850 | 6.75 | 5 |
| 21 | 14 | 11.0 | 117 | 2.5 | 3000 | 7.56 | 5 |
| 22 | 14 | 16.0 | 101 | 2.5 | 2875 | 7.83 | 5 |
| 23 | 17 | 8.5 | 93 | 2.0 | 2563 | 5.63 | 4 |
| 24 | 17 | 8.5 | 93 | 3.0 | 2425 | 4.26 | 3 |
| 25 | 17 | 8.5 | 109 | 2.0 | 2725 | 5.21 | 3 |
| 26 | 17 | 8.5 | 109 | 3.0 | 2906 | 6.79 | 3 |
| 27 | 17 | 13.5 | 93 | 2.0 | 2525 | 4.25 | 4 |
| 28 | 17 | 13.5 | 93 | 3.0 | 2325 | 3.54 | 2 |
| 29 | 17 | 13.5 | 109 | 2.0 | 2850 | 7.83 | 4 |
| 30 | 17 | 13.5 | 109 | 3.0 | 2875 | 7.33 | 1 |
| 31 | 20 | 11.0 | 101 | 2.5 | 2750 | 5.80 | 5 |

well as the interaction of floor time and water absorption (p=0.01) had a significant effect on bread quality.

The RSM design showed that 5 (Table XXI and XXII) out of 31 combinations of four variables should produce bread of optimum quality. Baking runs were conducted to confirm the predictions made by the RSM study. Combination 4 was predicted to yield high loaf volume, whereas doughs made with this combination were very sticky and difficult to manage. Combination 1 and 2 were predicted to produce good volume but the bread quality was poorer than those of combination 3 and 5. Therefore, doughs made with combination 3 and 5 were judged to produce bread with the best loaf volume and quality.

## Conclusion

Before turbo grinding, bran, shorts, red-dog and feed showed highly significant differtences in TDF (p=0.0001). The amount of TDF present in these fractions remained the same after turbo grinding (p=0.19). However, air classification separated fractions having highly significant differences (p=0.0001) in amount of TDF within each feed portion. Using four different settings of the air classifier produced significantly different amounts of TDF (p=0.03).

Table XXI. Statistical Analysis of Bread Volume Data for Five Combinations.

| LSMEAN # | Floor time (min) | Mixing time (min) | Water absorp. (%) | Fermentation time (hr) | Volume LSMEAN (cc) |
|---|---|---|---|---|---|
| 1 | 11 | 8.5 | 109 | 2 | 2833.00 |
| 2 | 11 | 8.5 | 109 | 3 | 2879.25 |
| 3 | 11 | 13.5 | 109 | 3 | 2898.50 |
| 4 | 14 | 11.0 | 117 | 2.5 | 2905.50 |
| 5 | 14 | 16.0 | 101 | 2.5 | 2861.75 |

Note: Comparison of p value of each combination is listed below.

| I/J | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | ** | 0.13 | 0.05 | 0.04 | 0.32 |
| 2 | 0.13 | ** | 0.49 | 0.36 | 0.53 |
| 3 | 0.05 | 0.49 | ** | 0.79 | 0.22 |
| 4 | 0.04 | 0.36 | 0.79 | ** | 0.15 |
| 5 | 0.32 | 0.53 | 0.22 | 0.15 | ** |

Level of significance = 5%.

Table XXII. Statistical Analysis of Bread Quality Data for Five Combinations.

| LSMEAN # | Floor time (min) | Mixing time (min) | Water absorp. (%) | Fermentation time (hr) | Quality LSMEAN (point) |
|---|---|---|---|---|---|
| 1 | 11 | 8.5 | 109 | 2.0 | 6.57 |
| 2 | 11 | 8.5 | 109 | 3.0 | 6.68 |
| 3 | 11 | 13.5 | 109 | 3.0 | 7.46 |
| 4 | 14 | 11.0 | 117 | 2.5 | 7.18 |
| 5 | 14 | 16.0 | 101 | 2.5 | 7.67 |

Note: Comparison of p value of each combination is listed below.

| I/J | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | ** | 0.63 | 0.008 | 0.03 | 0.003 |
| 2 | 0.63 | ** | 0.01 | 0.06 | 0.005 |
| 3 | 0.008 | 0.01 | ** | 0.24 | 0.36 |
| 4 | 0.03 | 0.06 | 0.24 | ** | 0.07 |
| 5 | 0.003 | 0.005 | 0.36 | 0.07 | ** |

Level of significance = 5%.

In this study wheat bran increased dough absorption and mixing time. Including bran in white bread changed dough processing. Both absorption and mixing time were increased relative to doughs without bran. Changes in water absorption ($p=0.05$), mixing time ($p=0.02$), and fermentation time ($p=0.03$) exerted significant influences on bread volume. However, floor time ($p=0.26$) had no significant effects on bread volume. Water absorption ($p=0.0001$), mixing time ($p=0.005$) and fermentation time ($p=0.003$) had very significant inferences on bread quality, while floor time ($p=0.01$) showed significant effects on bread quality.

Doughs made with combination 3 and 5 (Table XXI and XXII) had the best dough handling characteristics, although they did not yield the highest bread volume. These two combinations nonetheless gave good bread volume (2800 cc) and excellent crumb grain, and also produced the best dough handling properties.

High TDF material (60.8% TDF Table III) can be produced only through turbo grinding and air separation. By means of the adjustment of bread formula and modification of dough making condition, a good fiber bread can be readily made. No pre-treatment of fiber material before using in bread-making is needed.

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# PREPARATION OF HIGH TOTAL DIETARY FIBER MATERIAL FROM WHEAT MILL FEED, AND ITS UTILIZATION IN BREADMAKING


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## ABSTRACT

Although fiber materials can be often produced by wet milling, the process still can not be completed without drying of the product. Our interest was in producing fiber materials directly with a dry milling process. Dietary fiber was obtained by a process involving turbo grinding and air separation. By means of this method, on line mechanical dry separation of dietary fiber can be achieved. Using this method and no chemical processing, products were characterized by containing 60.8% total dietary fiber (TDF).

High fiber bread was made with no pre-treatment of wheat bran. In order to produce bread with reduced calories, shortening was replaced with emulsifiers. The bread volume (2800 cc) and quality (7.6) were improved by the adjustment of bread formulation and dough processing.

Several dough-making factors such as dough water absorption, mixing time, fermentation time etc. were studied by screening experiments (one variable at a time method). The interaction among water absorption, mixing time, fermentation time, and floor time was observed by response surface methodology (RSM). RSM predicted production of good fiber bread using two combinations of these four variables.