Effects of Barley Flour on the Quality and Acceptability of Home Baked Yeast Breads

보리가루 혼합 식빵의 質과 기호에 관한 연구

Department of Home Economics Education, Kwan Dong College
Instructor; **Myung Sook Jang**
Department of Home Economics California State University, L.A.
Professor; **Margaret McWilliams**

관동대학 가정교육과
전임강사 장 명 숙

캘리포니아 주립대학교 가정과
교 수 마아가렛 · 맥윌리암스

<Contents>

<적 요>

본 연구는 각각 다른 비율의 보리가루가 (0, 20, 30, 40%) 섞여진 Home Made Yeast Breads의 質과 기호에 대한 조사로 Penetrometer와 Volumeter를 사용한 객관적 평가와, Korean과 Caucasian의 Panelists에 의한 주관적 평가가 이루어졌다.

결과로 보리가루의 量이 증가함에 따라 Objective와 Subjective Score의 평균치가 감소하였지만 20% 이상의 보리가루가 혼합된 식빵이라도 문화적 배경에 관계없이 받아들여 질수있고 전반적으로 Korean이 Caucasian 보다 보리가루 섞인 식빵을 더 좋아 하는 것으로 나타났다.

Ⅰ. INTRODUCTION

As the population of the world constantly increases, the price of food rises and the shortage of food continues. These circumstances generate a greater demand to increase not only production, but also efficiency in the direct utilization of food resources.

Barley, one of the world's oldest domesticated crops[1], is a winter grain which is hardy and drought-resistant[2]. It is widely used in America as feed, but in many other areas, particularly in Asia, it has been used for centuries for human food[3]

Barley is one of the world's major staple food grains and one of the major farm products in Korea. Agrictultural policies have been directed toward increasing barley production through improved varieties. A public campaign has been implemented to attempt to change the dietary pattern of the people to include barley as an important grain in the national diet. The short growing season of barley makes it more dependable than wheat in the Korean climate. The low cost of barley in comparison with wheat makes barley a popular grain among Korean lower income groups.

Although barley is used primarily as a source of carbohydrate, the protein content is of considerable importance. The levels of most of the essential amino acids composing the protein are higher than in any other cereals[4,5]. The mineral and B vitamins content of barley are higher than those of wheat[6~8]. To attempt to enhance its nutritional value still more, an intensive search has been conducted for barley with elevated levels of lysine and methionine, regardless of other characteristics[9~15].

From the earliest times to the present day barley has been used as human food. Barley is eaten in many forms. Westward, its main use was as malt. Eastward, barley became an improtant grain. It has been used for centuries like rice, served as an accompaniment to meat or fish, and as a beverage by Asian people[3,16].

Flat barley bread was widely consumed in Europe from before Roman times to close to the present day[17]. In America, as a food, barley is used as flour or meal for persons allergic to other grains, for infants or invalids, as a breakfast food, and as pearl barley for thickening soups[1,18]. In recent studies, rolled high-lysine barley meal was replaced in breakfast cereal, cookies, and bread as an alternative to oatmeal. There was no significant difference in preference[19].

The best way to improve the utilization of barley in meeting world food problems is to use as large a portion as possible directly for human food. Breads are consumed widely around the world. Since they are made with a large proportion of grain, breads offer the possibility of utilizing a significant amount of barley in a food accepted by people of various cultures, including Koreans.

The purpose of this study was to investigate the effects of barley flour supplementation on the quality and acceptability of yeast bread by groups who have different cultural backgrounds. Specifically, the objectives of this investigation were:

1. To study the effect of barey flour supplementation on the quality and acceptability of yeast breads containing various levels of barley flour.

2. To investigate the difference of quality and acceptability of yeast breads containing various levels of barley flour between Koreans and Caucasians.

Ⅱ. PROCEDURE

Preparation of Yeast Breads

Breads containing three different levels

of barley flour were prepared by replacing 0 (control), 20, 30, and 40 percent of the wheat flour with barley flour. Except for the variation in flour, other ingredients remained the same. The experiment consisted of ten replications.

Materials

The ingredients used in preparing the bread were: all purpose flour (Gold Medal), barley flour, active dry yeast, warm water, whole milk, sugar, salt, and shortening. Barley flour[1] was obtained from a local natural food market, and the other ingredients were purchased from a local supermarket at the beginning of the experiment and were stored tightly wrapped, in a refrigerator(12°C) of the laboratory. The formula and variations are shown in Table 7.

Procedure for Bread Baking

Wheat flour and barley flour were blended with a wooden spoon (except 100 percent wheat flour).

Milk was scalded to 45°C(113°), while the yeast was softened in the water at 35°C (95°F) for 5 minutes.

Sugar and salt were put in a mixing bowl, and the scalded milk was added in the bowl. The yeast-water mixture was added to the milk mixture when the milk cooled to 35°C(95°F) and then stirred 50 strokes with a wooden spoon.

Two hundred grams of the flour were added and stirred 30 strokes with a wooden spoon. Another 150g of flour were added and stirred 20 strokes.

Table 7. Formulas for Breads Made with and without the Addition of Barley Flour

Ingredients	Percentage of Barley Flour Added			
	0	20	30	40
All purpose flour	400g	320g	280g	240g
Barley flour	0	80g	120g	160g
Dry yeast	7g	7g	7g	7g
Sugar	12g	12g	12g	12g
Salt	6g	6g	6g	6g
Shortening	8g	8g	8g	8g
Water(35°C)	40ml	40ml	40ml	40ml
Milk(45°C)	236ml	236ml	236ml	236ml

The dough was kneaded 400 times with the heels of both hands on a board floured with the remaining 50g of flour. After kneading had been completed, the dough was coated very lightly with oil and placed in a bowl. Then the bowl was covered with waxed paper.

The dough was allowed to proof for 45 minutes in a water bath maintained at 35°C. After proofing, the dough was punched down, and kneaded 10 times on a board.

The dough was shaped into an oblong loaf, and placed in a $9^1/_4 \times 4^1/_4 \times 2^3/_4$ inch aluminum loaf pan greased lightly on the bottom. The pan was then returned to the water bath for 30 minutes to rise for the second time.

Meanwhile, the oven was preheated to 205°C (400°F). After the end of the second proofing, the pan was removed from the water bath and placed in the center of a

[1] Orowheat Foods Company, 4052 28th Ave., S.W. Seattle, Washington 98126.

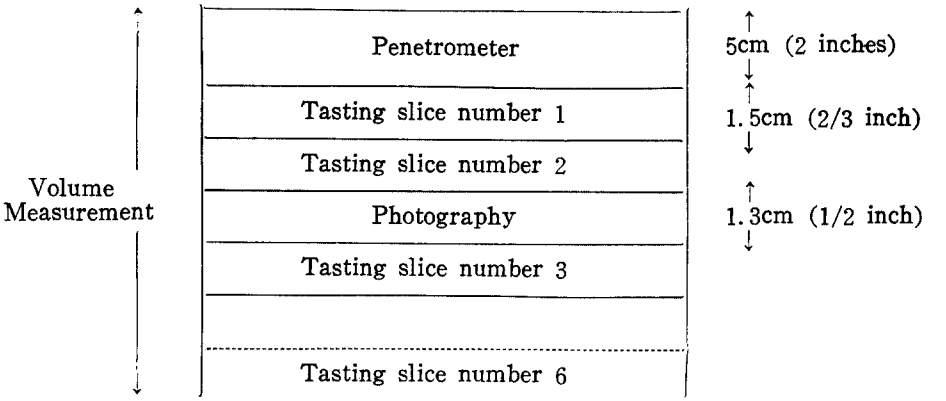

Fig. 1. Slices Used for Objective and Subjective Tests of Yeast Breads.

preheated gas oven and baked at 205°C (400°F) for 35 minutes. After baking, the bread was removed from the pan immediately. It was cooled on a wire rack for tests.

Evalvtion

Breads prepared in this investigation were judged both objectively and subjectively.

Slicing and Preparation of Samples for Testing

After baking, the loaves were removed from the pans and cooled for 30 minutes for volume measurement. When they had cooled to room temperature, the loaves were sliced for objective and subjective tests (Fig. 1).

Ojective Evaluations

Two objective measures were used as a basis for evaluating breads in this study: (1) volumetric measurement, and (2) measurement of tenderness.

Volumetric measurement. The volumes of breads were determined by rape-seed displacement in a volumeter (Appendix B) after being cooled 30 minutes. The volumes of each of the samples were used to determine the mean.

Measurement of tenderness. A "Humboldt" universal penetrometer with a cone-shaped attachment was used to measure the tenderness of the samples (Appendix C). A slice of bread 5 cm thick (Figure 1) was used. Five readings per slice were taken at the top, middle, and bottom, and held for 20 seconds.

Photography

The bread loaves and slices used for subjective viewing were photograp hed.

Subjective Evaluation

The taste panel selected for the study included three Korean students majoring in food and nutrition, and three Caucasian employees of California State University,

Los Angeles. Prior to the actual study, panel members were given written instructions (Appendix D) and the opportunity to participate in one trial session.

In judging the products, the panel members used a score sheet to evaluate qualities and acceptability of the breads (Appendix E). The score sheet used in this research was developed, based on principles discussed by Amerine[20] The characteristics evaluated were texture, flavor, crust and crumb color, mouth-feel of crust and crumb, tenderness of crumb, and overall acceptability. Texture was evaluated on the basis of the appearance of the bread. Specifically, size and uniformity of cell and thickness of cell walls were incorporated in the score of texture.

The rating scale used was 5--very good, 4--good, 3--fair, 2--poor, and 1--very poor. Samples were identified by symbols. The samples were placed on a white paper plate and a glass of tap water was provided to clear the palate between tasting each sample.

Statistical Analysis

The data obtained in this study were statistically analyzed using the t-test, the one-way, and two-way analysis of variance[21].

Ⅲ. RESULTS AND DISCUSSION

Objective Evaluations

Loaf Volum

The measured mean volume of the loaves ranged from 2,146 to 1,465cc (Table 8). With increasing amounts of barley flour, the volume of loaves decreased (Figure 2). Graphic presentation of data is shown in Figure 3. Calculation for significant difference among the volumes by a one-way analysis of variance showed that there was a significant difference at the 0.01 level with 38 degrees of freedom (Table 9). When the t-test was employed to assess the differences between samples, significance at the 0.01 level was shown between the samples (Table 10). It was hypothesized before the start of the study that there is a significant difference in volume between breads made with various levels of barley flour and bread made without barley flour. Based on the data from the analysis of variance, the hypothesis was accepted. The dough lacked elasticity, and no oven spring was observed

Table 8. The Mean Volume of the Breads

Percentage of Supplementation Wheat Flour : Barley Flour			Volume(cc)
100	:	0	2,146
80	:	20	1,942
70	:	30	1,707
60	:	40	1,465

Table 9. One-Way Analysis of Variance for the Loaf Volume of Breads Made with and without Barley Flour

Source of Variation	Degrees of Freedom	Mean Squares	F-Value[a]
Bread samples	3	936,167	
Error	38	5,318	176.1

[a]Significantly different at the 0.01 level.

Fig. 2. General Appearance of Breads Made with and without Barley Flour (Proportions of Barley Flour from Left to Right: 0, 20, 30, and 40 percent)

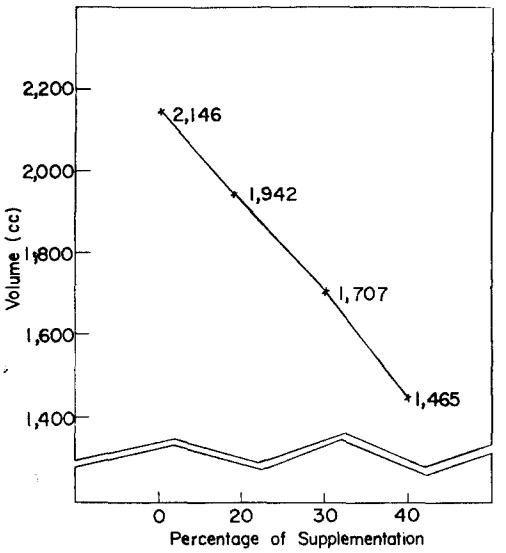

Fig. 3. The Volume of the Breads made with and without Barley Flour.

by increasing the amount of barley flour. The dough containing higher amounts of barley flour was distinctly dry, suggesting that additional liquid may be required in doughs in which barley is an ingredient. Some factors may be responsible for volume differences. First, in the barley breads, the amount of gluten formed after mixing is decreased in proportion to the amount of barley flour supplemented. The other factor noted was that with a decrease

Table 10. Resultsof the t-Test for Volume of Breads with Four Levels of Barley Flour Supplementation

Sample Pairs Tested	tValue[a]
0 and 20 percent barley flour breads	6.24[b]
0 and 30 percent barley flour breads	12.69[b]
0 and 40 percent barley flour breads	20.84[b]
20 and 30 percent barley flour breads	8.69[c]
20 and 40 percent barley flour breads	19.89[c]
30 and 40 percent barley flour breads	8.94[c]

[a]Significant difference at the 0.01 level.
[b]Degrees of Freedom = 20.
[c]Degrees of Freedom = 18.

in gluten formation, the bread dough decreased in elasticity and extensibility, affecting the bread (McWilliams, 1974; Huebner, 1977).

Tenderness Measured with the Penetrometer

Mean scores of penetrometer readings are shown in Table 11 and Fig.4. These ranged from 11.3 to 15.2mm. An alalysis of variance indicated that there was a significant difference at the 0.01 level among these readings (Table 12). According to the t-test(Appendix F), there was

no significant difference at the 0.01 level with 20 degrees of free dom the control bread and the bread containing 20 percent barley flour, and between the 20 percent sample and the 30 percent sample. Based on these data from the analysis of variance, the hypothesis that there is significant difference in tenderness between breads made with and without barley flour was supported.

Subjective Evaluations

The variables evaluated by the taste panel members were texture, flavor, crust and crumb color, mouth-feel of crumb and crust, tenderness of crumb, and overall acceptability. The appearance of the cut surface of breads is illustrated in Fig. 5. Bread samples were scored on a scale ranging from 5 to 1, with 5 being very good and 1 being very poor. The mean scores of the judges for the quality characteristics and overall acceptablility of breads made with the addition of various levels of barley flour are shown in Tables 13, 14, and 15.

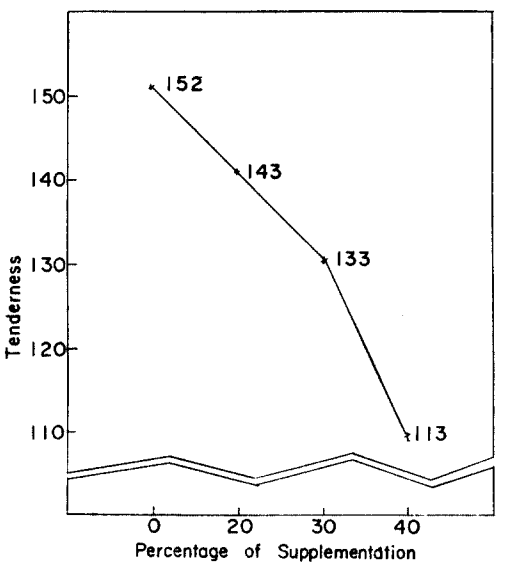

Fig. 4. The Tenderness of Breads made with and without Barley Flour as Measured with the Penetrometer.

Table 11. Mean Scores of Penetrometer Readings for Tendeness of Breads

Percentage of Supplementation Wheat Flour: Barley Flour			Readings of Penetrometer (mm)
100	:	0	15.2
80	:	20	14.3
70	:	30	13.3
60	:	40	11.3

Table 12. One-Way Analysis of Penetrometer Scores for the Tenderness of Breads Made with and without Barley Flour

Source of Variation	Degrees of Freedom	Mean Squares	F-Value[a]
Bread samples	3	2,869	
Error	38	167	17.2

[a]Significant difference at the 0.01 level.

Characteristics of Quality

Texture. The mean score for texture of the control bread was the highest of the samples, while 40 percent barley flour-supplemented bread was the lowest of the breads (Table 13). The F value indicated that there was a significant difference at the 0.01 level with 38 degrees of freedom among the samples(Table 16). Korean panelists gave higher scores for all samples than did the Caucasian panelists(Tables

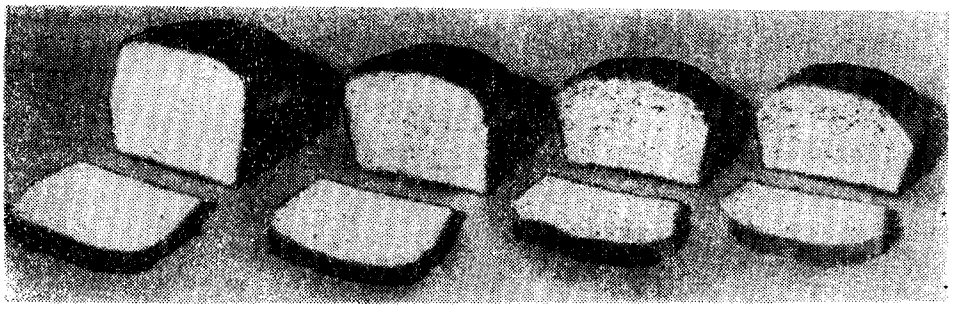

Fig. 5. Appearance of the Cut Surface of Breads made with and without Barley Flour (Proportions of Barley Flour from left to right: 0, 20, 30, and 40 percent)

Table 13. The Mean Scores of Total Panel Members for the Quality Characteristics of Breads[a]

Characteristics	Percentage of Barley Flour Supplementation to Wheat Flour			
	0	20	30	40
Texture	4.15	4.03	3.32	3.10
Flavor	4.38	3.93	3.59	3.20
Crust color	4.63	4.22	3.95	2.99
Crumb color	4.65	4.02	3.57	3.08
Mouth-feel of crust	4.47	3.98	3.68	3.07
Mouth-feel of crumb	4.49	3.99	3.52	3.05
Tenderness of crumb	4.50	3.99	3.62	3.08
Overall acceptability	4.58	4.07	3.65	3.05

[a]Ranked from 5 very good to 1 very poor.

Table 14. The Mean Scores of the Korean Panel Members for the Quality Characteristics of Breads[a]

Characteristics	Percentage of Barley Flour Supplementation to Wheat Flour			
	0	20	30	40
Texture	4.56	4.43	3.57	3.20
Flavor	4.81	4.43	3.93	3.47
Crust color	4.95	4.67	4.20	3.33
Crumb color	4.94	4.37	3.77	2.63
Mouth-feel of Crust	4.72	4.37	3.90	3.24
Mouth-feel of Crumb	4.86	4.36	3.53	3.00
Tenderness of Crumb	4.92	4.37	3.73	3.00
Overall acceptability	4.94	4.40	4.93	3.13

[a]Ranked from 5 verygood to 1 very poor.

14 and 15). Analysis of variance showed there was no significant difference at the 0.01 level(Table 17) between the two groups. The judges on the taste panel often commented that the 40 percent sample was crumbly or compact, and there was some heaviness near the bottom of the loaf. This difference may be due to lack of gluten which retains gas cells, or to insufficient fermentation time. Judges also indicated that the top surface of the loaves supplemented with barley flour was slightly rough, and crumb texture was coarser by increasing the amount of barley flour.

Flavor. The control bread had the highest mean score for flavor. The bread supplemented wiht 20 percent barley flour received a score close to the control bread (Table 13). The 40 percent sample had the lowest mean score for flavor. A

Table 15. The Mean Scores of the Caucasian Panel Members for the Quality Characteristics of Breads[a]

Characteristics	Percentage of Barley Flour Supplementation to Wheat Flour			
	0	20	30	40
Texture	3.75	3.57	3.07	2.99
Flavor	3.92	3.43	3.27	2.93
Crustcolor	4.22	3.84	3.60	2.67
Crumb color	4.36	3.77	3.37	2.89
Mouth-feel of crust	4.28	3.65	3.53	2.98
Mouth-feel of crumb	4.14	3.63	3.50	3.10
Tenderness of crumb	4.14	7.73	3.57	3.20
Overall acceptability	4.22	3.73	3.36	2.97

[a]Ranked from 5--very good to 1--very poor.

Table 16. One-Way Analysis of Variance of Total Judges Scores for the Texture of Breads

Source of Variation	Degrees of Freedom	Mean Squares	F-Value[a]
Bread samples	3	2.84	
Error	38	−0.14	−20.29

[a]Significantly different at the 0.01 level.

Table 17. Two-Way Analysis of Variance of Judges Scores Between Koreans and Caucasians for the Texture of Breads

Source of Variation	Degrees of Freedom	Mean Squares	F-Value[a]
Bread samples	3	0.53	0.46
Judges	1	0.71	0.62
Error	3	1.14	

[a]No significant difference at the 0.01 level.

significant difference at the 0.01 level was shown among these samples(Table 18). Korean panelists scored the products higher than the Caucasians did for all samples (Tables 14 and 15). One Korean judge scored the bread containing 30 percent barley flour higher than the other samples. One Caucasian judge gave a highe (score to the 20 percents sample than to the control bread. At the 20 percent level, barley flavor in bread was acceptable to both the Korean and the Caucasian judges. There was a significant difference at the 0.01 level in acceptance of barley flavor between the two groups (Table 19).

Crust color. The control bread had the highest score for crust color while the 40 percent sample had the lowest score. However, the score for the 20 percent sample was very close to the control bread(Table 13). There was a significant difference at the 0.01 level among the samples (Appendix G, Table 22). Korean panel members scored the crust color higher than the Caucasians did (Tables 14 and 15). A significant difference at the 0.01 level was found between the two groups (Appendix G, Table 23). Some panelists commented that the color of crust was slightly lighter with barley flour supplementation than the control bread.

Crumb color. Crumb color of the control bread received the highest score while the mean of 40 percent sample had the lowest score(Table 13). This indicated that the taste panelists preferred the creamy white color to which they were accustomed. A significant difference at the 0.01 level was found in scores for crumb color (Appendix

Table 18. One-Way Analysis of Variance of Total Judges Scores for the Flavor of Breads

Source of Variation	Degrees of Freedom	Mean Squares	F-Value[a]
Bread samples	3	2.55	
Error	38	0.074	34.45

[a]Significant difference at the 0.01 level.

Table 19. Two-Way Analysis of Variance of Judges Scores Between Koreans and Caucasians for the Flavor of Breads

Source of Variation	Degrees of Freedom	Mean Squares	F-Value[a]
Bread samples	3	0.49	28.82
Judges	1	1.19	70.00
Error	3	0.017	

[a]Significant difference at the 0.01 level.

G, Table 24). Korean panelists gave higher scores to the 0, 20, and 30 percent samples, but the Caucasian panelists gave a higher score to the 40 percent sample than the Koreans did (Tables 14 and 15). A significant difference at the 0.01 level was found between the two groups (Appendix G, Table 25). Judges indicated that the crumb color was getting darker by increasing the amount of barley flour.

Mouth-feel of crust. Among the mean scores for mouth-feel of crust, the control bread had the highest score; the 40 percent barley sample had the lowest score (Table 13), but the 20 and 30 percent samples received the scores closest to the control. Analysis of variance indicated that there was a significant difference at the 0.01 level among the samples (Appendix G, Table 26). Although the Korean panel members gave higher scores for all samples than the Caucasians did (Table 14 and 15), Caucasian panelists rated the 20 percent as being acceptable. There was a significant difference at the 0.01 level between the groups (Appedix G, Table 27). Judges indicated that the crust of breads supplemented with barley flour became rougher and tougher as the amount of barley flour was increased. This appears to be due coarse fractions of barley flour.

Mouth-feel of crumb. The control bread had the highest score, while the 40 percent sample had the lowest score (Table 13). Analysis of variance indicated that there was a significnt difference at the 0.01 level between the samples (Appendix G, Table 28). Korean panelists gave higher scores to the 20 percent and 30 percent samples than the Koreans did. The Korean and Caucasian panelists scored the 30 percent samples very closely (Tables 14 and 15). There was no significant difference at the 0.01 level between two groups (Appendix G, Table 29).

Tenderness of crumb. The mean scores for tenderness of the crumb are shown in Table 13. The analysis of variance indicated that there was a significant difference between the samples (Appendix G, Table 30). The 20 percent sample received a good rating, although it was not as high as the score for the control. With the exception of the 40 percent barley sample, the Korean judges scored the barley breads higher than the Caucasians did (Table 13). The higher the percentage of barley flour, the less tender

the breads were judged to be. Judges scores for tenderness showed the same results as the penetrometer readings for tenderness. Korean Panelists gave higher scores to all samples except the 40 percent sample than the Caucasians did, but both groups gave good scores for the 20 percent and 30 percent samples (Tables14 and 15). There was no significant difference at the 0.01 level between the groups (Appendix G, Table 31).

Overall Acceptability

The scores of overall acceptability showed relationships among the samples smilar to those for the individual characteristics. The control bread received the highest score, and the 40 percent samples had the lowest score. The scores of the 20 and 30 percent samples were close to those of the control bread(Table 13). There was a significant difference at the 0.01 level between the sample (Appendix G, Table 32). The Koreans rated higher scores than did the Caucasians for all the samples (Tables 13 and 14). A significant difference at the 0.01 level existed between the two groups(Appendix G, Table 33).

Under the conditions of this study, the differences in characteristics of quality between the control bread and the 40 percent barley flour-supplemented bread were the greatest. Breads with 20 and 30 percent barley were judged to be close in quality to the bread made without barley flour. Most of the judges preferred the control bread.

Ⅳ. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary and Conclusions

The purpose of this study was to determine the quality and acceptability of home made yeast breads containing 0, 20, 30, and 40 percent barley flour. Subjective evaluation was conducted with Korean and Caucasian panelists to determine the relationship of cultural background to acceptance of barley bread.

The percentage of barley flour used in bread significantly affected all tests, both objective and subjective. The loaf volume was decreased by increasing the amounts of barley flour. Breads containing barley flour also decreased in tenderness, the crumb became darker, coarser, and more compact, and crust color became lighter. However, there was no significant difference in the tenderness between the control bread and the bread supplemented with 20 percent barley flour, and between the breads containing 20 and 30 percent barley flour.

Although the control bread was judged the highest for every factor, the bread containing 20 percent barley flour also received high scores for all characteristics, and the bread containing 30 percent barley flour was scored in the acceptable range. The 40 percent barley flour-supplemented bread was scored the lowest for every factor, but was still acceptable to the

Korean panelists. Most of the the characteristics were judged to be significantly different among the four breads. Korean panelists gave higher scores for all characteristics than the Caucasians did. There were no significant differences between the two groups in texture, mouth-feel of crumb, and tenderness. Even though significant difference was found between the two panel groups in overall acceptability, the Caucasian panelists scored the bread containing 20 percent barley flour in the high range, and the bread containing 30 percent barley flour was scored as acceptable. Therefore, it is possible that bread supplemented with barley flour up to 30 percent would be acceptable for people in any country, and the level could go as high as 40 percent in countries using barley as one of the main staples.

Recommendations

The following recommendations are submitted for further research:

1. Ideal fermentation temperatures, times, and amount of liquid for the bread dough containing barley flour may be studied.

2. It would be interesting to use barley flour as an extender in making puddings, noodles, and quick breads.

Ways of solving the world food problem and improving nutritional quality are of vital concern today. The researcher hopes that more study using barley flour, referred to as one of the cheapest grains and as one of a good amino acid-balanced grain, will be conducted by interested people.

BIBLIOGRAPHY

1. Stewart, G.F., and M.A. Amerine. 1973. Introduction to Food Science and Technology. London and New. York: Academic Press, pp. 4-7.
2. Bland, B.F. 1972. Crop production: Cereals and Legumes. London and New York: Academic Press, pp. 71-72.
3. Pekkarinen, M. 1973. World food consumption patterns. In Man, Food, and Nutrition, ed. M. Rechigl, Jr. Cleveland, Ohio: CRC Press, pp. 19-20.
4. Jones, A. 1974. World Protein Resources. Lancaster, England: Medical and Technical Publishing Co. Ltd., pp. 155-160.
5. Adair, C.R. 1972. Production and utilization of rice. In Rice Chemistry and Technology, ed. D.F. Houston. St. Paul, Minnesota: American Association of Cereal Chemists, p. 11.
6. Liu, D.J., G.S. Robbins, and Y. Pomeranz. 1974. Composition and utilization of milled barley products. Ⅳ. Mineral components, Cereal Chem., 51 : 309-315.
7. Clutterbuck, V.J., and D.E. Briggs. 1974. Phosphate mobilization in grains of "Hordum Distichon." Phytochemistry 13 : 45-54.
8. Kent, N.L. 1973. Technology of Cereals with special References to Wheat. London: Pergamon Press, pp. 43-73.
9. Munck, L., B.O. Eggum, and A. Gagberg. 1970. Gene for improved nutritional value in barley seed protein. Science 158 : 985-987.
10. Green, C.E., and R.L. Philips. 1974. Potential selection system for mutants with increased lysine, threonine, and methionine in cereal crops. Crop Science 14 : 827-830.
11. Ingversen, J. and B. Kφie. 1971. Protein-

patterns of some high lysine barley lines. Hereditas 69 : 319-323.

12. Pomeranz. Y., G. S. Robbins, J.T. Gilbertson, and G.D. Booth. 1977. Effects of nitrogen fertilization on lysine, threonine, and methionine of hulled and hull-less barley cultivars. Cereal Chem. 54 : 1034-1042.
13. Briggs, D.E. 1978. Barley. London: Chapman & Hall, pp. 81-85, 492-522.
14. El-Negoumy, A.M., C.E. Newman, and G.R. Moss. 1979. Amino acid composition of total protein and electrophoretic behavior of protein fractions of barley. Cereal Chem. 56 : 468-473.
15. Martens, H. 1980. Fractioning barley proteins by computer factor analysis. Cereal Chem. 57 : 97-105.
16. Pomeranz, Y. 1973. Industrial use of barley. In Industrial Uses of Cereals. Symposium proceedings. St. Paul, Minnesota: American Association of Cereal Chemists, pp. 372-374.
17. Tannahill, R. 1973. Food in History. New York: Stein and Day, pp. 36-80.
18. Pomeranz, Y. 1977. Barley, In Elements of Food Technology, ed. N.W. Desrosier. Westport, Connecticut: The Avi Publishing Company, Inc., pp. 175-176.
19. Prentice, N., W.C. Burger, and B.L. D'Appollnia. 1979. Rolled high-lysine barley in breakfast cereal, cookies, and bread. Cereal Chem. 56 : 413-416.
20) Amerine, M.A., R.M. Panborn, and E.B. Roessler. 1965. Principles of Sensory Evaluation of Food. New York, London: Academic Press.
21) Walpole, R.E., and R.H. Myers. 1978. Probability and Statistics for Engineers and Scientists. New Work: Macmillan Publishing Co., Ind.