Effects of Malting Conditions on Quality Characteristics of Malt and Roasted Malt Extract

K. O. KIM,[1] M. K. KIM,[1] Y. Y. KANG,[2] and Y. C. LEE[2]

ABSTRACT   Cereal Chem. 70(4):440–442

The effects of malting conditions (germination period and drying temperature) on the proximate composition of barley malt and on the sensory quality of roasted malt extracts were examined. Response surface methodology was used to find optimum malting conditions based on sensory quality. Proximate composition of malt was affected by malting conditions. Germinating barley for four days and drying at 77°C were found to be the optimum malting conditions for high sensory quality roasted malt extract.

Roasted barley tea, hot or cold, is consumed frequently by most Korean families. Recently, a barley beverage was developed commercially and became a popular drink. The beverage is produced using roasted barley with added sweeteners, flavoring materials, etc. It is recognized as healthier and more nutritious than many other beverages.

During germination, barley produces many enzymes that hydrolyze starch and protein (MacLeod et al 1964, MacLeod 1967), such as α-amylase (MacGregor and Ballance 1980, MacGregor and Matsuo 1982), β-amylase, and protease. Generally, green malts are dried by increasing the temperature of airflow in a stepwise fashion from 50 to 90°C to preserve the enzyme activity for brewing. Typical malt flavor is developed during drying and can be manipulated by the heating conditions (Runkel 1975). Sugars and amino acids in malt undergo the Maillard reaction, producing flavored compounds when heated. The reaction is accelerated at higher temperatures (Whistler and Daniel 1985). Therefore, it was thought that roasted malt could be used instead of roasted barley to produce a barley beverage with more desirable flavor.

Response surface methodology (RSM) is a valuable tool used to find optimum levels of two or more treatment variables. RSM has been described in the literature (Box and Wilson 1951, Mead and Pike 1975) and successfully used for food processing operations by several investigators (McLellan et al 1984, Mudahar et al 1989, Artz et al 1990).

The objective of this study was to examine the effects of malting conditions on the quality of malt and roasted malt extract and to find optimum conditions of malting (germination and drying) for the production of roasted malt extract with high sensory quality that could be used for a roasted barley beverage.

MATERIALS AND METHODS

Malting

A six-rowed variety of barley, Olbory, commonly used for malting, was purchased locally from Korean producers. Barley aliquots (2 kg, as is) were cleaned and steeped (~70 hr) at 15°C to 45% moisture. During steeping, the water was changed every 24 hr. The grain was turned periodically to help prevent bacterial growth between kernels. After steeping was complete, the grains were removed from the water and placed in beds to germinate for 2, 4, and 6 days at 15°C. Water was sprayed on the grain twice a day for the first three days and then three times per day for the remainder of the germination period to maintain 80–90% rh. At the end of a predetermined period of germination, green malts (45% moisture content) were placed in an air-circulating pilot

drier (Pacific Scientific Instrument Co., Seoul, Korea) and dried at 65, 75, or 85°C for 15 hr. After the rootlets were removed, malts were refrigerated (4°C) in air-tight bags.

Measurement of Proximate Composition of Malt

Starch content was calculated from the amount of reducing sugar hydrolyzed from starch by hydrochloric acid. Reducing sugar was determined by Schoorl method (method 14.025, AOAC 1980). Protein was calculated from nitrogen content determined by micro-Kjeldahl method (method 14.068, AOAC 1980) using a conversion factor of 6.25. Free amino acid was determined by the method described by Friedman et al (1984). The analysis was conducted in duplicate.

Malt Roasting and Extraction

Malt samples (~400 g) were roasted (250°C, 3 min) in a pilot roaster (model Duett-M, Probat, Emmerich, Germany) to the same lightness value of 50 using a reflectionmeter (model 670, Photovolt, NY). Roasted malts were ground and then stored at 4°C until extraction. Roasted malt samples (5 g) were extracted in a percolator (Empire Supreme, Metal Ware Co., Two Rivers, WI) with 400 ml of water for 10 min and filtered using generic coffee filters.

Sensory Evaluation

Seven graduate students majoring in food science at Ewha Woman's University evaluated the overall acceptability and roasted flavor of roasted malt extract. The evaluation was conducted in partitioned booths in a sensory evaluation laboratory under low-intensity red light to mask color differences between samples. Before the actual evaluation sessions started, panelists were familiarized with terminology, characteristics of samples to be tasted, and test techniques and procedures. Samples (30 ml, 65°C) were placed into vials coded with three-digit numbers, covered, and presented to each panelist. Water and unsalted crackers were used to cleanse the palate between samples. The panelists assigned scores to samples using a nine-point hedonic scale for overall acceptability (1 = dislike extremely, 9 = like extremely) and a seven-point category scale for roasted flavor (1 = weak, 7 = very strong).

Experimental Design and Statistical Analysis

Nine samples from a three-level two-factor design (Table I) and one additional centerpoint sample were withdrawn using the

central composite factorial design of RSM. To prevent fatigue due to too many samples, sensory evaluation was performed according to the balanced incomplete-block design (plan 11.16, Type III) described by Cochran and Cox (1957). Four randomized samples were presented simultaneously and tested at each session by seven panelists for 15 sessions, allowing six test replicates. The RSM program (McKesson Technical Center, Dublin, CA.) was applied to calculate β coefficients for the Taylor second-order expansion equations using estimated mean values of sensory scores. Analysis of variance tables and RSM plots also were constructed. From superimposed plots of response, optimum malting conditions for high sensory quality of roasted malt extracts were determined.

RESULTS AND DISCUSSION

Proximate Composition of Malt

The proximate composition of malt is shown in Table II. Starch content decreased as the germination period was extended. Reducing sugar content markedly increased with the longer germination period, as expected from the decrease of starch. Protein content decreased slightly. Total free amino acid content increased more obviously as germination proceeded. These changes probably were caused, in part, by the increased enzyme activity during germination, as mentioned earlier. Drying temperature had little effect on starch and protein contents. Some decreases in reducing sugar and total free amino acid content were noticed at higher drying temperatures. These decreases may be attributed to the Maillard reaction occurring at the high drying temperature (Hodge and Osman 1976, Rhee and Rhee 1981).

Sensory Quality of Roasted Malt Extract

As shown in Table III, overall acceptability increased as germination was extended to four days, and it slightly decreased

TABLE I
Treatment Variables of Malting Conditions

	Levels		
Variables	−1	0	1
Germination period (X_1, days)	2	4	6
Drying temperature (X_2, °C)	65	75	85

TABLE III
Estimated Means[a] for Overall Acceptability and Roasted Flavor Under Different Malting Conditions

Treatment[b] No.	Germination Period		Drying Temperature		Overall Acceptability	Roasted Flavor
	Coded	Actual (Days)	Coded	Actual (°C)		
1	−1	2	−1	65	3.72	3.14
2	−1	2	0	75	4.24	3.53
3	−1	2	1	85	4.16	3.45
4	0	4	−1	65	5.57	4.52
5	0	4	0	75	5.58	5.05
6	0	4	0	75	5.57	5.00
7	0	4	1	85	5.20	5.42
8	1	6	−1	65	4.79	3.45
9	1	6	0	75	5.39	4.14
10	1	6	1	85	5.43	4.61

[a]Values are of six test replicates with seven panelists.
[b]Experiments were run in random order.

TABLE II
Proximate Composition[a] of Barley and Malts Prepared with Different Germination Periods and Drying Temperatures

Germination Period (days)	Drying Temperature (°C)	Moisture (%)	Starch (%)	Reducing Sugar (%)	Protein[b] (%)	Free Amino Acid (%)
0	...	12.05	48.3	1.14	13.0	0.31
2	65	8.25	49.3	0.55	13.1	0.83
2	75	8.00	48.5	0.76	13.0	0.54
2	85	7.05	42.7	0.75	12.7	0.48
4	65	6.60	37.3	6.12	12.6	1.04
4	75	6.45	35.5	7.06	12.7	1.00
4	85	6.05	34.2	6.09	12.2	0.87
6	65	7.05	20.2	8.61	12.2	1.32
6	75	6.05	21.2	9.79	12.4	1.18
6	85	5.30	23.2	9.29	12.5	1.07

[a]Means of two replicates (dry-weight basis).
[b]N × 6.25.

TABLE IV
Analysis of Variance of the Effects of Malting Conditions on
Acceptability and Roasted Flavor of Roasted Malt Extract

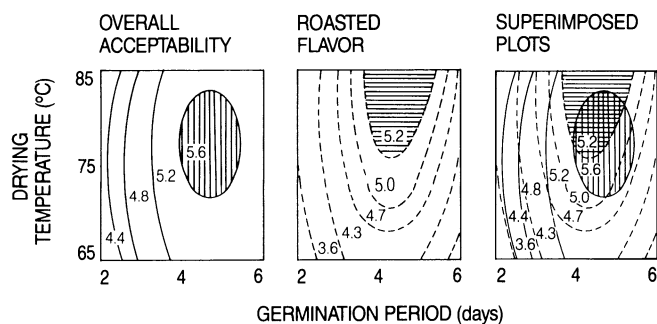| | | F-value | |
| | | Overall | Roasted |
Source	DF	Acceptability	Flavor
First order	2	628.15[a]	236.47[a]
Second order	2	567.73[a]	563.83[a]
Interaction	1	5.94	51.55
Lack of fit	3	55.51	1.89
Percent variability explained (R^2)		93.46	99.58

[a]Significant at 5% level.

Fig. 1. Contour plots of response variables at different germination periods and drying temperatures.

thereafter. Drying temperature did not seem to affect overall acceptability as much as germination period did. Roasted flavor was maximum at the four-day germination period and increased with elevated drying temperature.

Optimum Malting Conditions

Analysis of variance for the response variables is given in Table IV. Overall acceptability and roasted flavor scores of the roasted malt extract were modeled with both linear and quadratic effects ($P < 0.05$). There were no significant interaction effects for both response variables. Lack of fit was not significant. The percent variability explained by the model (R^2) was quite high for the response variables, indicating adequacy of the model. The Taylor expansion equations using coded values for the two treatment variables, germination period (X_1) and drying temperature (X_2), are as follows:

$$Y_1 = 5.604 + 0.582X_1 + 0.118X_2 - 0.817X_{12} - 0.247X_{22}$$

$$Y_2 = 5.059 + 0.347X_1 + 0.395X_2 - 1.257X_{12} - 0.122X_{22}$$

where Y_1 is overall acceptability and Y_2 is roasted flavor score.

As shown in contour plots (Fig. 1) drawn using these model equations, overall acceptability was the highest at four to five

days of germination and 70–83°C drying temperatures. Roasted flavor scored highest at four to five days of germination and gradually intensified as the temperature increased within the experimental range. Optimum malting conditions were selected to obtain maximal overall acceptability and roasted flavor. Because rootlets (removed after drying) of germinating barley became longer as germination proceeded, the final malt yield was reduced (data not shown). The shortest germination period was selected within the optimum range, and the optimum drying temperature was chosen within these limits (see superimposed plots in Fig. 1). With these considerations, optimum malting conditions for the production of roasted malt extract with high sensory quality for use in barley beverages were: four-day germination period and 77°C drying temperature.

LITERATURE CITED

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1980. Official Methods of Analysis, 13th ed. The Association: Washington, DC.

ARTZ, W. E., WARREN, C., and VILLOTA, R. 1990. Twin screw extrusion modification of a corn fiber and corn starch extruded blend. J. Food Sci. 55:746.

BOX, G. E. P., and WILSON, K. B. 1951. On the experimental attainment of optimum conditions. J. R. Stat. Soc. 13:1.

COCHRAN, W. G., and COX, G. M. 1957. Balanced and partially balanced incomplete block designs. Pages 439-482 in: Experimental Designs. John Wiley and Sons: New York.

FRIEDMAN, M., PANG, J., and SMITH, G. A. 1984. Ninhydrin-reactive lysine in food protein. J. Food Sci. 49:10.

GIOVANNI, M. 1983. Response surface methodology and product optimization. Food Technol. 37(11): 41.

HODGE, J. E., and OSMAN, E. 1976. Carbohydrates. Pages 41-138 in: Principles of Food Science. I. Food Chemistry. O. Fennema, ed. Marcel Dekker: New York.

MacGREGOR, A. W., and BALLANCE, D. L. 1980. Hydrolysis of large and small starch granules from normal and waxy barley cultivars by alpha-amylase from barley malt. Cereal Chem. 57:397.

MacGREGOR, A. W., and MATSUO, R. R. 1982. Starch degradation in endosperms of barley and wheat kernels during initial stages of germination. Cereal Chem. 59:210.

MCLELLAN, M. R., BARNARD, J., and QUEALE, D. T. 1984. Sensory analysis of carbonated apple juice using response surface methodology. J. Food Sci. 49:1595.

MacLEOD, A. M., DUFFUS, J. H., and JOHNSTON, C. S. 1964. Development of hydrolytic enzymes in germinating grain. J. Inst. Brew. 70:521.

MacLEOD, A. M. 1967. The physiology of malting. A review. J. Inst. Brew. 73:146.

MEAD, R., and PIKE, D. J. 1975. A review of RSM from a biometrics viewpoint. Biometrics 31:803.

MUDAHAR, G. S., TOLEDO, R. T., FLOROS, J. D., and JEN, J. J. 1989. Optimization of carrot dehydration process using response surface methodology. J. Food Sci. 54:714.

RHEE, K. S., and RHEE, K. C. 1981. Nutritional evaluation of the protein in oilseed products heated with sugars. J. Food Sci. 46:164.

RUNKEL, U. D. 1975. Malt kilning and its influence on malt and beer quality. Eur. Brew. Conv. Monogr. 11:222.

WHISTLER, R. L., and DANIEL, J. R. 1985. Carbohydrates. Pages 69-137 in: Food Chemistry, 2nd ed. O. R. Fennema, ed. Marcel Dekker: New York.