Optimum Roasting and Extraction Conditions and Flavor Characteristics of Roasted Malt Extract

Yang Kim,[1] Young Choon Lee,[2] and Kwang Ok Kim[1,3]

ABSTRACT

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Malt was roasted at 235, 245, or 255°C and extracted at 75, 85, or 95°C in hot water for 10, 20, or 30 min. Optimum roasting and extraction conditions were chosen using response surface methodology based on sensory and physicochemical properties. Sensory properties of roasted malt extract produced at optimum conditions were compared with those of roasted barley extract and of commercial barley tea using quantitative descriptive analysis. Flavor compounds in roasted malt extract were identified by gas chromatography (GC) and mass spectroscopy (MS). Correlation between sensory and GC-MS data were calculated. Roasting malt at 240°C and extracting at 75°C for 28 min were found to be optimum conditions for roasted malt extract. The results of sensory and GC-MS data indicated that the most dominant flavor compounds in roasted barley and malt were aldehydes and pyrazines.

Because of its typical flavor, roasted barley tea is consumed widely in Korea. Barley tea that is roasted at high temperature can result in bitter taste and burnt flavor rather than roasted flavor. Most flavor compounds in roasted barley tea are produced by pyrolysis and the amino-carbonyl reaction during roasting. Limited published data are available on conditions of barley tea production and flavor characteristics. Extent of roasting is mainly determined by the color of the kernels. Wang et al (1968) and Suh et al (1981) reported that the brownness of barley during roasting was a good indicator for the flavor produced, and roasting time and temperature had a great effect on the color and yield of barley tea. Roasting temperature is also known as an important factor for coffee flavor, in addition to grain size and extraction conditions (Sivetz and Foote 1963). Therefore, it seems that roasting and extraction conditions could be important factors for the quality of grain extracts including barley.

Because sugars and amino acids are produced during germination of barley, roasted malt can be successfully used for the preparation of barley tea with more desirable flavor. Optimum malting conditions for malt extract were established, and feasibility of malt extract for the production of a beverage was suggested in previous study (Kim et al 1993). The relationship between flavor compounds and sensory characteristics was thought to be an useful tool for monitoring the flavor quality of food or beverage.

This study was designed to establish optimum roasting and extraction conditions of malt for extract preparation, and to compare the flavor properties of malt extract roasted at optimum conditions with those of roasted barley extract through quantitative descriptive analysis and gas chromatography.

MATERIALS AND METHODS

Malting

Olbory, a six-rowed barley cultivar commonly used for malting was purchased from local producer in Korea. Malt was prepared as in Kim et al (1993). Barley aliquots (2 kg, as-is basis) were cleaned and steeped (70 hr) at 10°C to ≈45% moisture. The water was changed every 24 hr during steeping. After steeping, the grains were removed from the water and placed in beds for malting at 15°C for four days. At the end of germination, green malts were dried in an air-circulating pilot drier (Pacific Scientific Instrument Co., Seoul, Korea) at 75°C for 15 hr to 10% moisture content. After the rootlets of dried malts were removed, the malts were refrigerated (4°C) in air-tight bags (400 g/bag).

Experimental Design for Optimization of Roasted Malt Extract Production

The process variables examined were roasting temperature, extraction temperature, and time. Fifteen malt samples including three centerpoints (Table I) were selected according to the second-order response surface design (Box and Behnken 1960).

To prevent fatigue due to too many tastings in sensory evaluation, a replicated incomplete block design was used. Accordingly, three randomly selected samples were presented simultaneously to seven judges in each session. Sensory evaluation was repeated five times on different days.

Preparation of Roasted Malt Extract for Optimization

Malt samples (400 g) were roasted in a pilot roaster (model Duett-M, Probat, Emmerich, Germany) with the discharge temperature at 235, 245, or 255°C, while the air temperature of the roasting drum was fixed at 300°C. Roasted malt samples were ground to a fine level using a coffee grinder (model 850, Grindmaster, Louisville, KY) and stored at 4°C until extraction.

Roasted malt powder (25 g, dry basis) was extracted with preheated water (1 L) at 75, 85, or 95°C in a water bath. The slurry was stirred with an impeller (200 rpm) for 10, 20, or 30 min and then filtered with generic coffee filters (Brew Rite, Rockline Ind., Sheboygan, WI). Extracts were kept in a freezer (–18°C) until analyzed.

Color, Yield, and Turbidity of Roasted Malt Powder and Extract

The samples for color measurement were placed in the transparent plastic plates (40 mm × 5 mm, diameter depth) with a lid. The color values (*L*, *a*, and *b*) of roasted malt extract were measured using a color meter (model CR300, Minolta Camera Co., Osaka, Japan). Yield of the extract was calculated from solid content of the roasted malt extract obtained by drying at 105°C for 24 hr in an air-drying oven (model 0445, Dongyang Science Co., Seoul, Korea). Turbidity was determined by measuring absorbance at 610 nm using a spectrophotometer (Spectronic 601, Milton Roy Co., Rochester, NY).

Sensory Evaluation of Roasted Malt Extract

The sweet flavor, burnt flavor, sour taste, and overall desirability of roasted malt extracts were evaluated by seven trained panelists. The panelists were students in the Department of Foods and Nutrition at Ewha Womans University who had taken a sensory evaluation course at least for one semester. They were trained for 1 hr/day five times a week for a month. They participated in evaluation when they showed reproducibility. At each evaluation

[1] Research associate and professor, respectively. Department of Foods and Nutrition, Ewha Womans University, 120-750, Seoul, Korea.
[2] Professor, Department of Food Science and Technology, Chung-Ang University, 456-756, Ansung, Kyunggi-do, Korea.
[3] Corresponding author. Phone/Fax: 82-2-360-3095. E-mail: kokim@mm.ewha.ac.kr

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session, three samples (30 mL, at 65°C) were presented in vials wrapped with aluminum foil to mask the color differences. An unstructured line scale (15 cm) was used, which was labeled as weak and strong for flavors and as undesirable and desirable for overall desirability at 1.25 cm from both ends. The panelists indicated the intensity of each attribute or degree of overall desirability by placing a vertical line on the scale.

Statistical Analysis for Roasted Malt Extract

To determine significant effects, the data were subjected to a three-way analysis of variance (ANOVA) using general linear model (GLM) procedures (SAS Institute, Cary, NC). Duncan's multiple range test (SAS) was performed to determine significant differences among treatment means. Response surface methodology (RSM) was used to determine optimum roasting and extraction conditions for malt extract production based on maximum overall desirability.

Preparation of Malt and Barley Extracts for Quantitative Descriptive Analysis

The same type of barley was used for preparation of roasted malt and barley extracts. Malt was prepared in the same manner described above and roasted under the optimum roasting conditions derived from the earlier experiment. Roasted barley was prepared by roasting to the same lightness (≈37 for L value) as the roasted malt sample. Commercial barley tea (Dongsuh Food Co., Inchon, Korea) was purchased from local market. All the grain samples were ground and refrigerated (4°C) in air-tight bags. Roasted malt extract was prepared with the optimum extraction temperature and time. Roasted barley extract and commercial barley tea were prepared under the same conditions as the roasted malt extract.

Quantitative Descriptive Analysis

Seven graduate students were selected as panelists for quantitative descriptive analysis (QDA). Three out of seven participated in the previous test. The training was conducted with various roasted malt extracts and roasted barley extracts prepared under different conditions. During three weeks of training, the panelists determined descriptive terms to characterize roasted malt and barley extracts prepared under various roasting and extraction conditions. Nine descriptive terms with 15-cm unstructured line scales were used for the evaluation. The samples were freshly prepared on each evaluation day and presented in the manner described earlier.

TABLE I
Treatment Variables of Roasting and Extraction Conditions for Roasted Malt Extract Production

	Levels		
Variables	**–1**	**0**	**1**
Roasting temperature (X_1) (°C)	235	245	255
Extraction temperature (X_2) (°C)	75	85	95
Extraction time (X_3) (min)	10	20	30

TABLE II
Reference Samples and the Scale Values for Sensory Attributes in Quantitative Descriptive Analysis

Sensory Attribute	Reference Sample Preparation	Scale Value
Sweet odor	Corn syrup (5 g) (Shinsong Food Co., Korea) dissolved in 500 mL of hot water.	10.0
Mouth coating	Rice (30 g) (Akibare cultivar) boiled in 400 mL of water for 7 min.	6.0
Astringency	Brown rice and green tea (4.5 g) (Dongsuh Food Co., Korea) brewed in 400 mL of hot water for 6 min.	10.0
Bitterness	Caffeine solution (0.05%).	6.0

Reference samples were provided for each descriptive term, and the scores for the references were predetermined by the panelists and anchored on the scales (Table II). The evaluation was conducted under dim red light.

Statistical Analysis for QDA

The QDA data were subjected to a three-way ANOVA using GLM procedures and Duncan's multiple range test (SAS). Correlation coefficients were computed for all sensory attributes evaluated. Principal component analysis (PCA) was applied to examine the interrelation of sensory properties (SAS). PCA on the correlation matrix was generated from the sensory ratings for each sample across all attributes.

Flavor Compounds of Roasted Malt Extract and Roasted Barley Extract and Barley Tea

Volatile flavor compounds were trapped by the dynamic headspace method, and subjected to the identification by gas chromatography (GC) and mass spectroscopy (MS). Volatile compounds in 20 g of sample were trapped with a purge and trap system (Tekmar LSC 2000, Cincinnati, OH). The GC equipment used for the separation of volatile compounds was a Hewlett-Packard model 5890 equipped with a DB-5 fused-silica capillary column and flame ionization detector. Injector and detector temperatures were set at 230 and 250°C, respectively. Oven temperature was initially set at 35°C, and then increased to 220°C at a rate of 1.5°C/min. A Hewlett-Packard model 5972 mass selective detector (GC/MSD) was used to identify volatile flavor compounds. The electron voltage and scan range were 70eV and 30–350 m/e, respectively. Other conditions were identical to those of the GC procedure.

RESULTS AND DISCUSSION

Color, Yield, and Turbidity of Roasted Malt Extract

Mean values and contour plots of color, yield, and turbidity of roasted malt extract are shown in Table III and Fig. 1. ANOVA for the response variables is shown in Table IV. The color properties

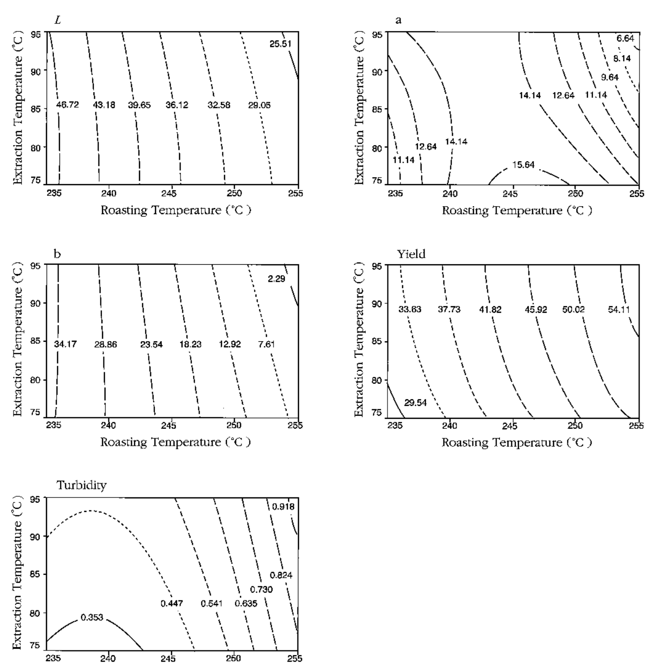

Fig. 1. Contour plots for color (L, a, and b), yield, and turbidity of roasted malt extracts at all combinations of roasting and extraction temperatures with extraction time fixed at 28 min.

(*L*, *a*, and *b*), yield, and turbidity of roasted malt extract were more greatly affected by roasting temperature than extraction conditions (Table IV). As the roasting temperature increased, the *L* value of roasted malt extract decreased. The value of *a* increased with roasting temperature up to 245°C and then decreased (Fig. 1). With increased roasting temperature, *b* value decreased, indicating decreased yellowness. The extraction conditions had no effect on *L* and *a*, whereas they had a significant effect on *b* value. The higher extraction temperature and the longer extraction time resulted in decreased *b* values. Color of roasted products like coffee can be an indicator for flavor characteristics (Sivetz and Foote 1963). Therefore, the extent of roasting is commonly determined by its color. Because of Maillard reaction by sugars and free amino acids in malt (Whistler and Daniel 1985), roasted malt could give darker color than the roasted barley.

All three conditions affected yield. The interaction between roasting temperature and extraction temperature and the interaction between roasting temperature and extraction time also showed significant effects on yield, but the roasting temperature had much a greater effect than did the extraction conditions (Table IV). It has been known that higher roasting temperature promotes pyrolysis causing the change in the physicochemical structure of starch, resulting in higher soluble solids content (Yoon et al 1989). In this experiment, yield of roasted malt extracts was predicted to be the range of 27–56% by the results of RSM analysis (Fig. 1). Kim et al (1989) applied a hydrolytic enzyme treatment (α, β-amylases and protease) to barley for increased yield. Yield increased from 20 to 52–70% with the treatment. Barley produces the enzymes during malting, thus the increase of yield in roasted malt is expected due to the enzymatic action.

Turbidity is an important quality factor in beverages. Roasting and extraction conditions affected turbidity of roasted malt extracts (Table IV). There also were interaction effects. As described earlier, higher roasting and extraction temperatures increased the yield of roasted malt extract, thus increased turbidity could be expected. However, the increasing pattern of turbidity did not

TABLE III
Means[a] for Physicochemical Properties of Roasted Malt Extract Under Different Roasting and Extraction Conditions

Treatment No.	Roasting Temp. (°C)	Extraction Temp. (°C)	Extraction Time (min)	Color			Yield (%)	Turbidity (A)
				L	*a*	*b*		
1	235	75	20	49.49a	9.56d,e	37.20a	27.81i	0.326l
2	235	85	10	48.78a	10.56c,d	37.10a	27.52i	0.318m
3	235	85	30	48.38a	10.39d	36.48a	31.71h	0.429g
4	235	95	20	46.41a	12.82b	35.54a	31.01h	0.460f
5	245	75	10	40.31b	14.22a,b	26.66b	35.36g	0.362k
6	245	75	30	35.14c	16.39a	19.61c,d	39.04f	0.408i
7	245	85	20	38.00b,c	15.35a	23.28c	41.35e	0.387j
8	245	85	20	37.39b,c	15.01a	22.49c	41.35e	0.387j
9	245	85	20	36.85b,c	15.75a	22.23c	41.35e	0.387j
10	245	95	10	36.91b,c	15.68a	22.21c	41.71e	0.415h
11	245	95	30	34.49c	15.36a	18.18d	44.64d	0.525e
12	255	75	20	30.26d	14.36a,b	11.67e	48.77c	0.677d
13	255	85	10	28.20d,e	12.67b,c	8.22f	48.67c	0.729c
14	255	85	30	25.98e	7.46e	2.88g	55.43a	0.974a
15	255	95	20	25.20e	7.91e	3.15g	52.56b	0.812b

[a] Means of triplicates. Means followed by the same letter within a column are not significantly different ($P < 0.05$).

TABLE IV
Analysis of Variance of the Effects of Roasting and Extraction Conditions on Color, Yield, and Turbidity of Roasted Malt Extract

Source	DF	Sum of Square	*F*-value	Significance[a]
Color (*L*)				
Roasting temperature (RT)	2	872.40	337.29	***
Extraction temperature (ET)	2	18.96	7.33	
Extraction time (EM)	2	13.49	5.22	
Color (*a*)				
RT	2	81.81	8.18	***
ET	2	1.88	0.19	
EM	2	2.22	0.22	
Color (*b*)				
RT	2	1813.21	255.38	***
ET	2	32.26	4.54	
EM	2	39.03	5.50	
Yield				
RT	2	2863.1	2701.60	***
ET	2	144.87	136.70	***
EM	2	116.02	58.01	***
RT×ET	3	11.57	3.86	***
RT×EM	2	12.01	6.00	***
ET×EM	1	0.42	0.79	
Turbidity				
RT	2	1.3950	89524.0	***
ET	2	0.0722	4634.5	***
EM	2	0.1185	7606.8	***
RT×ET	3	0.0277	1183.2	***
RT×EM	2	0.0287	1838.6	***
ET×EM	1	0.0032	406.7	***

[a] *** = Significant at $P < 0.001$.

exactly coincide with that of yield (r = 0.84). The decreased turbidity with the higher roasting temperature could be due to the dissolution of starch and protein molecules in more soluble form in water, as reported by Yoon et al (1989).

The regression models and the values (R^2) of percent variability explaining color, yield, and turbidity are shown in Table V. The R^2 values were quite high, indicating adequacy of the models.

Sensory Properties of Roasted Malt Extract

Mean values and contour plots of sensory data for roasted malt extract are presented in Table VI and Fig. 2. As the roasting temperature increased, intensity of sweet flavor, and overall desirability decreased significantly (P < 0.01). All the sensory properties except burnt flavor decreased as the extraction temperature increased (P < 0.05). It could be due to the flavor changes at higher extraction temperature especially affecting sweet and burnt flavor. Longer extraction time resulted in the more sour taste.

ANOVA for the response variables is presented in Table VII. Roasting temperature showed greater effect than extraction conditions on sweet flavor, burnt flavor, and overall desirability. There were significant interaction effects between roasting temperature and extraction time on sweet flavor, between roasting temperature and extraction temperature on burnt flavor, between roasting temperature and extraction time, as well as between extraction temperature and extraction time, on overall desirability.

The regression models and R^2 values for sweet flavor, burnt flavor, sour taste, and overall desirability are shown in Table VIII. The R^2 values were all high, showing adequacy of the models.

Optimum Roasting and Extraction Conditions for Roasted Malt Extract

Optimum conditions for roasted malt extract production were selected considering expected values of yield and some sensory attributes calculated with the model (Tables V and VIII). To choose the key variables for optimization, correlation coefficients (r) were calculated between physicochemical and sensory properties and overall desirability. High positive correlation between sweet flavor and overall desirability (r = 0.96) and high negative correlation between burnt flavor and overall desirability (r = –0.94) were found.

The yield showed high positive correlation (r = 0.84) with turbidity, which could negatively affect beverage acceptability. Thus, sweet flavor and burnt flavor, which affected overall desirability of roasted malt extract, and the yield were chosen as key variables for optimizing malt roasting and extraction conditions. It is desirable for roasted malt extract to have more sweet flavor and less burnt flavor in the malt extract, and to have higher yield. Therefore, the sensory scores >10 in sweet flavor, and <5 in burnt flavor were set for limits of optimization. However, higher yield was accompanied with the increased burnt flavor, thus lowering overall desirability. Therefore, the yield value of 30%, which showed the least detrimental effect on the flavor properties, was chosen as

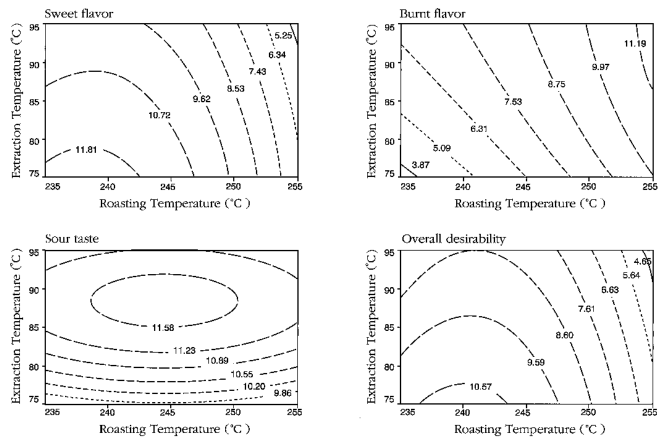

Fig. 2. Contour plots for sensory properties of roasted malt extracts produced at all combinations of roasting and extraction temperatures with extraction time fixed at 28 min.

TABLE V
Regression Equations Describing the Response of Color, Yield, and Turbidity

Parameter	Equation[a]	R^2
Brightness (L)	$633.1 - 4.326X_1 + 1.514X_2 + 0.544X_3 + 0.008X_1^2 - 0.005X_2^2 - 0.003X_3^2 - 0.005X_1X_2 + 0.007X_1X_3 - 0.004X_2X_3$	99.27
Redness (a)	$-3330 + 25.21X_1 + 5.243X_2 + 3.742X_3 - 0.047X_1^2 - 0.024X_2^2 + 0.005X_3^2 - 0.013X_1X_2 - 0.006X_1X_3 - 0.004X_2X_3$	93.24
Yellowness (b)	$-384.7 + 3.304X_1 + 4.089X_2 + 2.381X_3 - 0.006X_1^2 - 0.017X_2^2 - 0.007X_3^2 - 0.012X_1X_2 + 0.008X_1X_3 - 0.009X_2X_3$	99.54
Yield	$-463.8 + 2.477X_1 + 1.573X_2 - 1.123X_3 - 0.003X_1^2 + 0.001X_2^2 - 0.010X_3^2 + 0.006X_1X_2 - 0.002.X_1X_3 - 0.002X_2X_3$	99.32
Turbidity	$106.8 - 0.885X_1 + 0.004X_2 - 0.107X_3 + 0.002X_1^2$	99.39

[a] X_1 = roasting temperature, X_2 = extraction temperature, X_3 = extraction time.

TABLE VI
Means[a] for Sensory Attributes of Roasted Malt Extract under Different Roasting and Extraction Conditions

Treatment No.	Roasting Temp. (°C)	Extraction Temp. (°C)	Extraction Time (min)	Sweet Flavor	Burnt Flavor	Sour Taste	Overall Desirability
1	235	75	20	12.6a	5.8e–g	8.8c,d	10.6a,b
2	235	85	10	12.0a,b	4.3g	9.7b–d	11.3a
3	235	85	30	11.2a	4.2g	11.2a–c	8.8b,c
4	235	95	20	9.9c,d	7.2c–f	10.4a–d	9.2b,c
5	245	75	10	11.3a–c	6.4d–g	8.3d	9.1b,c
6	245	75	30	10.7a–d	5.3f–g	10.2a–d	10.6a,b
7	245	85	20	10.4b–d	9.2a–c	10.4a–d	9.9a–c
8	245	85	20	10.4b–d	8.8b–d	12.4c,d	10.2a–c
9	245	85	20	10.1b–d	8.3c,d	11.6a,b	8.7b,c
10	245	95	10	10.4b–d	7.8c–e	8.2d	9.9a–c
11	245	95	30	9.1d	8.7b–d	11.2a–c	8.3c
12	255	75	20	6.1e,f	11.1a,b	9.8b–d	5.1d
13	255	85	10	4.4f,g	11.3a	9.6b–d	4.1d
14	255	85	30	6.5e	11.1a,b	10.3a–d	5.2d
15	255	95	20	4.1g	11.1a,b	11.4a–c	4.3d

[a] Means of seven replicates. Means followed by the same letter within a column are not significantly different (P = 0.05).

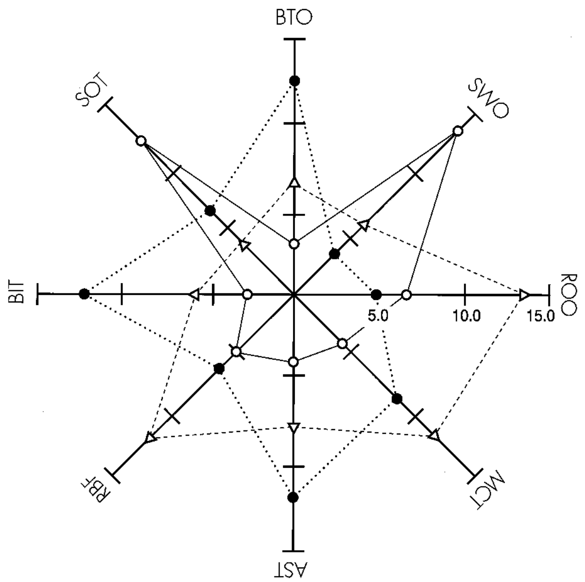

Fig. 3. Quantitative descriptive polygon of roasted malt extract (○), roasted barley extract (●), and commercial barley tea (Δ). BTO = burnt odor; SWO = sweet odor; ROO = roasted odor; MCT = mouth coating; AST = astringency; RBF = roasted barley flavor; BIT = bitter taste; SOT = sour taste. Values are means of four replicates. All values are significantly different at $P < 0.05$ among samples.

a constraint for optimization. With these constraints, roasting at 240°C and extraction at 75°C for 28 min were determined to be the optimum conditions for roasted malt extract production. Under these conditions, the predicted sensory scores for sweet flavor, burnt flavor, overall desirability, and predicted yield value (%) were 12.1, 4.8, 10.9, and 34.1, respectively.

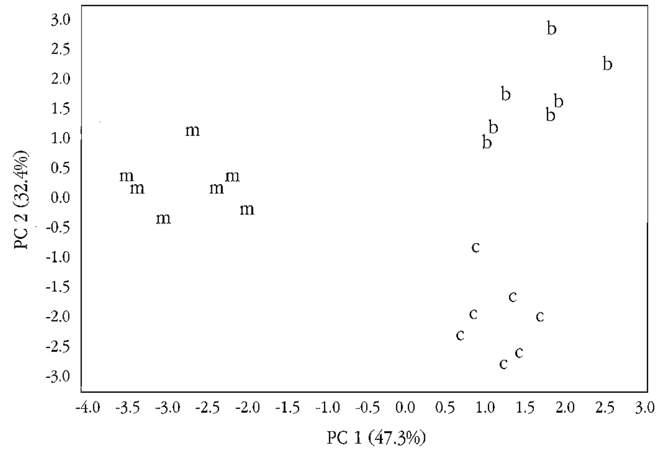

Fig. 4. Principal component (PC) scores of roasted malt extract (m), roasted barley extract (b), and commercial barley tea (c).

TABLE VII
Analysis of Variance Showing the Significance of the Effects of Roasting and Extraction Conditions on Sensory Properties of Roasted Malt Extract

Source	DF	Sum of Square	*F*-value	Significance[a]
Sweet flavor				
Roasting temperature (RT)	2	633.78	31.689	*
Extraction temperature (ET)	2	45.93	8.29	***
Extraction time (EM)	4	0.36	0.13	
RT×ET	1	6.28	0.57	
RT×EM	2	22.43	4.05	*
ET×EM	1	0.76	0.27	
Burnt flavor				
RT	2	477.13	58.07	***
ET	2	35.15	4.28	*
EM	4	0.18	0.04	
RT×ET	1	82.25	5.01	**
RT×EM	2	0.04	0.00	
ET×EM	1	7.61	1.85	
Sour taste				
RT	2	1.73	0.21	
ET	2	38.87	4.66	*
EM	4	43.93	10.52	**
RT×ET	1	34.91	2.09	
RT×EM	2	7.26	0.87	
ET×EM	1	2.12	0.51	
Overall desirability				
RT	2	513.91	94.16	***
ET	2	11.79	2.16	
EM	4	2.01	0.74	
RT×ET	1	1.55	0.14	
RT×EM	2	24.90	4.56	*
ET×EM	1	16.97	6.22	*

[a] *, ** , *** = Significant at $P < 0.05$, $P < 0.01$, and $P < 0.001$, respectively.

TABLE VIII
Regression Equations Describing the Response of Sensory Characteristics

Parameter	Equation[a]	R^2
Sweet flavor	$-1025 + 9.004X_1 - 0.221X_2 - 1.667X_3 - 0.020X_1^2 + 0.002X_2^2 - 0.002X_3^2 + 0.007X_1X_2 - 0.002X_1X_3 + 0.002X_2X_3$	98.10
Burnt flavor	$56.84 - 1.196X_1 + 1.360X_2 + 0.190X_3 + 0.004X_1^2 - 0.003X_2^2 - 0.003X_3^2 + 0.005X_1X_3 - 0.014X_2X_3$	94.53
Sour taste	$-286.3 + 1.730X_1 + 1.746X_2 + 0.715X_3 - 0.003X_1^2 - 0.010X_3^2 - 0.002X_1X_2 + 0.002X_1X_3 - 0.009X_2X_3$	78.12
Overall desirability	$-1180 + 1018X_1 - 0.174X_2 - 1.564X_3 - 0.022X_1^2 + 0.002X_2^2 - 0.01X_3^2 + 0.009X_1X_2 - 0.008X_1X_3$	98.10

[a] X_1 = roasting temperature, X_2 = extraction temperature, X_3 = extraction time.

Quantitative Descriptive Analysis

In all sensory attributes, significant differences ($P < 0.01$) were shown among roasted malt extract, roasted barley extract, and commercial barley tea (Fig. 3). As shown in Fig. 3, roasted malt extract had much higher values in sweet odor and sour taste, whereas it had lower values in burnt odor, bitter taste, mouth coating, and astringency when compared to roasted barley extract and commercial barley tea. The properties of roasted barley extract, such as burnt odor and bitter taste, could be due to overroasting.

The principal component (PC values) for data (analysis eigenvalues >1.0) (Johnson and Dean 1982) were chosen for the analysis of results in PCA. The first two PC values accounting for 80% of the variance were selected. The rotated factor loadings of the ratings of nine sensory attributes were plotted on the PC1 (*x*) and PC2 (*y*) dimensions with attributes as vectors (Fig. 4). Sweet odor and sour taste were loaded negatively on PC1, while burnt odor, mouth coating, astringency, and bitter taste, were loaded positively on PC1. Attributes loaded in the same direction (positive or negative) indicate positive correlation with one another.

In superimposed plots (data not shown) of Figs. 4 and 5, roasted malt extract existed in the same matrix with the attributes, such as

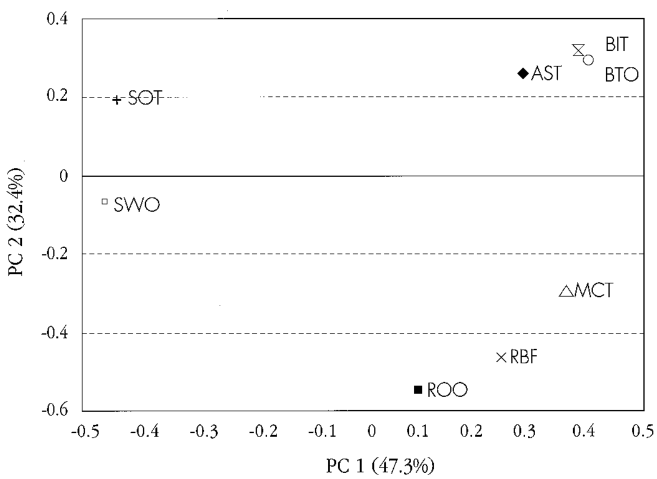

Fig. 5. Principal component (PC) loadings of sensory attributes of roasted malt extract, roasted barley extract, and commercial barley tea. BTO = burnt odor; SWO = sweet odor; ROO= roasted odor; MCT = mouth coating; AST = astringency; RBF = roasted barley flavor; BIT = bitter taste; SOT = sour taste.

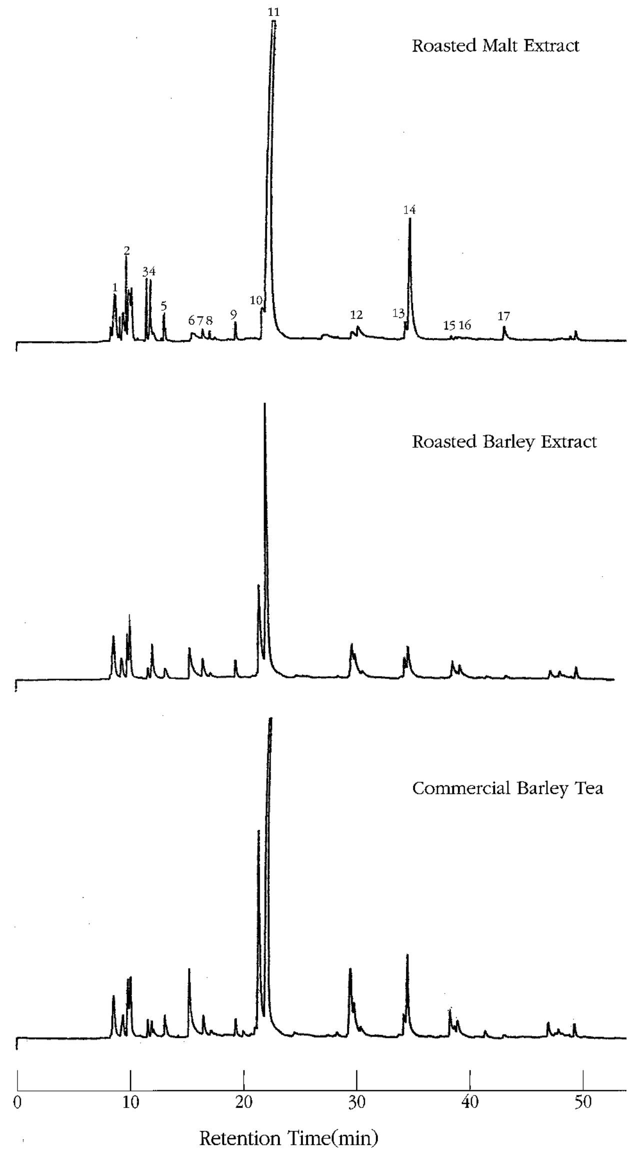

Fig. 6. Gas chromatograms of roasted malt extract, roasted barley extract, and commercial barley tea.

TABLE IX
Major Flavor Compounds of Roasted Malt and Barley Extracts and Barley Tea

Peak No.	Retention Time (min)	Compounds[a]	Roasted Malt Extract[b]	Roasted Barley Extract[b]	Commercial Barley Tea[b]
1	8.601	Butane	245	200	226
2	9.321	3-Methyl-2-butane	110	97	98
3	11.415	2-Butanone	104	40	27
4	11.763	1-Butanol	114	41	124
5	12.993	3-Methyl-butanal	43	78	49
6	15.190	Pyrazine	19	306	196
7	16.445	Methyl-benzine	34	66	87
8	17.264	Pyridine	18	10	25
9	19.366	Hexanal	39	53	58
10	21.755	Methyl pyrazine	77	693	41
11	22.370	2-Furancarboxaldehyde	2,826	1,859	1,029
12	30.216	2,6-Dimethyl-pyrazine	104	187	148
13	34.164	Benzaldehyde	56	69	86
14	34.825	5-Methyl-2-furancarboxaldehye	638	303	190
15	38.605	Methyl-ethyl-pyrazine	10	97	82
16	39.223	2-Ethyl-3-methyl-pyrazine	20	66	101
17	43.391	Bezeneacetaldehyde	63	15	18

[a] Means of triplicates.
[b] Area count/10,000.

TABLE X
Correlation Coefficients (*r*) Between Sensory Characteristics and Flavor Compounds by Gas Chromatography

Peak No.	Compound	Roasted Malt Extract	Roasted Barley Extract	Commercial Barley Tea
1	Butane	–0.2613	0.6911	–0.8084
2	3-Methyl-2-butane	–0.7232	0.9654	–0.3870
3	2-Butanone	–0.8603	0.9993	–0.1690
4	1-Butanol	0.2766	0.2167	–0.9964
5	3-Methyl-butanal	–0.0087	–0.4706	0.9372
6	Pyrazine	0.4688	–0.8342	0.6577
7	Methyl-benzine	0.9586	–0.9781	–0.0761
8	Pyridine	0.6090	–0.1555	–0.9583
9	Hexanal	0.9062	–0.9981	0.0715
10	Methyl pyrazine	–0.2170	–0.2763	0.9893
11	2-Furancarboxaldehyde	–0.9773	0.9596	0.1509
12	2,6-Dimethyl-pyrazine	0.3790	–0.7754	0.7291
13	Benzaldehyde	0.9957	–0.9188	–0.2689
14	5-Methyl-2-furancarboxaldehye	–0.9012	0.9987	–0.0831
15	Methyl-ethyl-pyrazine	0.6560	–0.9371	0.4708
16	2-Ethyl-3-methyl-pyrazine	0.9694	–0.9687	–0.1169
17	Bezeneacetaldehyde	–0.7323	0.9688	–0.3746

sweet odor and sour taste. Reducing sugars and free amino acids produced during germination of barley produces various flavor compounds during roasting that give sweet odor through Maillard reaction. And sugars also are degraded into organic acids during the high-temperature roasting and extraction. This could explain sweet odor and sour taste of roasted malt extract. Roasted barley extract appeared in the same matrix with the sensory attributes of burnt odor, astringency, and bitter taste. These attributes are clustered together showing strong positive correlations. Burnt odor and bitter taste are generated in the roasting procedure, and roasted malt extract produces many brown pigments through amino-carbonyl reaction. Barley has fewer sugars and free amino acids, thus producing less brown pigment during roasting than malt. For lightness similar to that of the malt, barley was roasted six times under the same roasting conditions. Therefore, the burnt odor and bitter taste of roasted barley extract was higher than that of roasted malt extract, which could be partly due to overroasting. Panelists gave the highest score for commercial barley tea in roasted odor, mouth coating, and roasted barley flavor.

Flavor Compounds of Roasted Malt Extract, Roasted Barley Extract, and Commercial Barley Tea

Seventeen main peaks were separated from roasted malt extract, roasted barley extract, and commercial barley tea by GC (Fig. 6). Table IX shows volatile compounds identified by GC/MSD. The identified compounds included six aldehydes, five pyrazines, two alkanes, one ketone, one alcohol, and two others. It appeared that the predominant flavor compounds in roasted barley and malt were aldehydes and pyrazines.

Large variations were found in the contents of 2-furancarboxaldehyde, 5-methyl 2-furancarboxaldehyde, and methyl pyrazine among samples. The 2-furancarboxaldehyde was significantly higher in roasted malt and methyl pyrazine was significantly higher in roasted barley than in the other samples. Collin et al (1971) and Harding et al (1978) reported that methyl pyrazine, and 2,6-dimethyl pyrazine were the important pyrazine compounds in roasted barley. Roasting barley for 5–11 min resulted in increased amount of 2-furancarboxaldehyde, hexanal, and benzaldehyde (Kim 1996).

Table X shows the correlation coefficient (*r*) between sensory characteristics and flavor compounds by GC. Sweet odor, which was high in roasted malt (Fig. 3), appeared to be much affected by aldehydes (2-furancarboxaldehyde, 5-methyl-2-furancarboxaldehyde, and benzaldehyde). Pyrazines (including 2,6-dimethyl pyrazine, methyl-ethyl pyrazine, and pyrazine) had positive correlation with roasted odor. Suk (1987) indicated that pyrazines were identified in many roasted cereal products and could be responsible for roasted aroma. Methyl-benzene, hexanal, and 2-ethyl-3-methyl-pyrazine had significant positive correlation with burnt odor and had a negative correlation with sweet odor. This result could indicate that these compounds might have a negative effect on sensory quality of roasted malt or barley. However, further research would be necessary to verify the results.

CONCLUSION

Our results suggest that the roasted malt extract prepared at the optimum conditions had superior sensory properties when compared to commercial barley tea. It is expected that roasted malt extract could replace roasted barley tea and also be used for various other beverage productions.

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