Malting of Corn: Effect of Variety, Germination, Gibberellic Acid, and Alkali Pretreatments

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White and yellow corn varieties, MS1 and Vijay, steeped to 40% moisture were germinated at 25 °C for 3, 5, and 7 days with and without alkali pretreatments and gibberellic acid (GA). The yield of malt was satisfactory but for low diastatic power. α-Amylase activity was considerably increased by pretreatment with GA and longer germination. The Kolbach index of 7 days germinated white variety malt was higher and its wort perceptibly more yellow than that of the yellow variety. The presence of a starch fraction in the mash resistant to α-amylase action has been noted.

Among cereals, corn occupies the second position as regards global production (Food and Agricultural Organization, 1979). It is a heavy yielder and largely used as a feed grain. Industrially, corn is used for manufacturing starch and to a limited extent as an adjunct by the distilleries and breweries (Canales, 1979). Whereas malting of barley (Cook, 1962; Pollock, 1979) and wheat has advanced, corn has not received similar attention, so far. The objective of present investigation was to study the effect of variety, steeping, germination, and gibberellic acid (GA) treatments on the properties of corn malt.

MATERIALS AND METHODS

Two extensively grown varieties of corn, MS1 (white) and Vijay (yellow) were obtained from the University farms. The samples were cleaned and stored in airtight containers for use in various tests.

Germination Capacity. This was determined according to the method described by Cook (1962).

Water Sensitivity. Water sensitivity determines the extent to which germination of seed is influenced by excess moisture. Essery et al. (1954) prescribed 4 and 8 mL of water for wetting filter papers in Petri dishes used for testing the water sensitivity of barley. In the present investigation, 6–14 mL of water was used to wet the filter papers. One hundred corns in duplicate were taken in Petri dishes for germination at 25 °C. The number of germinating corns was counted daily for 6 days and reported as cumulative germination, %.

Experimental Malting. Weighed lots of corn (500 g) were steeped to 40% moisture contents at 25 °C with and without alkali pretreatment (0.05 N, NaOH) to loosen skin to facilitate germination. Steep water was changed every 3 h during the first 24 h and subsequently at 6-h intervals. The time of contact of corn with dilute alkali solution was 4 h followed by draining and washing free of alkali, and further steeping in water was same as in other cases. Gibberellic acid (2 ppm) was added to the final steep lasting 6 h. Germination was carried out at 25 °C for 3, 5, and 7 days by using wooden compartments (21.5 × 21.0 × 11.0 cm), with wire mesh bottoms for aeration. The samples were turned once a day, and each lot was sprayed with 3 mL of water to compensate for surface drying of lots in each compartment. The green malts were dried at 45 °C for 24 h by spreading in thin layers on perforated trays kept in a through-flow air dryer. The roots were gently removed by rubbing and sifting. The weights of roots and malt were recorded. Average moisture content of the finished malts was, for MS1, 7.5 ± 1.0% and, for Vijay, 7.2 ± 0.9%, respectively.

Moisture, ash, and protein contents were determined according to the American Association of Cereal Chemists (1976) methods. Starch was determined polarimetrically as described by Singh and Bains (1977).

Diastatic Power (DP). This was determined according to the Association of Official Analytical Chemists (1970) procedure and results are expressed as °L/100 g.

α-Amylase Activity (AA). The ICC colorimetric procedure described by Perten (1966) was followed and values are expressed as SKB/g.

Proteolytic Activity (PA). This was determined according to the method of Ayre and Anderson (1939) and the results are expressed as mg of soluble N/100 g.

Yield of Extract and Wort Quality. The malts were mashed according to the Association of Official Analytical Chemists (1970) procedure. The yield of extract as percentage by weight was determined by the European Brewery Convention (1953) method using specific gravity (20 °C/20 °C) equivalent of wort from the Plato tables. Conversion time, speed of filtration, and clarity of wort were also recorded. The color of wort was determined in the Lovibond tintometer. The wort was also analyzed for soluble N and for reducing sugars (Lane and Eynon, 1923). The buffer index $[(10/pH_1 - pH_2) \times E]$ was determined by the method of Van Laer (De Clerck, 1958), where E is the percentage of extract, pH_1 the initial pH, and pH_2 the pH after adding 1 mL of 0.1 N HCl to 25 mL of wort. The degree of modification was expressed as the Kolbach index (KI), which was calculated from the expression 100(total soluble N/total malt N). The results are expressed on a moisture-free basis.

RESULTS AND DISCUSSION

The white variety of corn, MS1, had higher hectoliter and kernel weights and about 1% more starch than the yellow variety, Vijay (Table I). The germination capacity of the varieties was 100% but for slightly more water sensitivity of MS1 than of Vijay (Table II). Maximum germination of Vijay occurred in the presence of 12–14 mL of water used for moistening the filter papers in Petri dishes as compared to 10 mL required by MS1. The steeping loss of Vijay corn was higher than that of MS1 (Table III). Alkali pretreatment caused higher steeping as well as malting losses.

Varietal differences in the percentage yield of malt were negligible although 7-day malts showed a considerable decrease as compared to the 5- and 3-day malts. Alkali pretreatment followed by application of GA reduced the malt yields, somewhat. The respiration losses were, on the whole, higher than the combined steeping and root losses.

Malting considerably reduced the hectoliter and 1000-kernel weights as germination was extended from 3 to 7

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Table I. Grain Characteristics of Corn Varieties

variety	hL wt, kg	1000-kernel wt, g	ash, %	protein ($N \times 6.25$), %	starch, %	germination capacity, %
MSI (white)	70.7	185.5	1.4	9.6	75.4	100
Vijay (yellow)	64.8	173.3	1.3	9.2	74.5	100

Table II. Effect of Water Content on Cumulative Germination of Corn Varieties at 25 °C

water content, mL	cumulative germination, %	
	MS1	Vijay
6	13	10
8	47	79
10	100	80
12	95	100
14	99	100

days (Table IV). A progressive decrease in the starch contents with the duration of germination was also observed. Some increase in protein contents occurred on malting for 7 days as compared to that of the controls.

Diastatic Power and α-Amylase Activity. The corn malts showed poorer diastatic power (Table V) than barley and wheat malts as reported by Singh and Bains (1977) and by Sethi and Bains (1978). Depending on malting treatments, DP values of barley and wheat ranged from

Table III. Effects of Malting Treatments on Yields of Corn Malts

germination, days	treatment	losses due to steeping, %		losses due to germination, %		losses due to root, %		malt yield, %	
		MS1	Vijay	MS1	Vijay	MS1	Vijay	MS1	Vijay
3	control	0.9	0.5	3.2	3.7	1.1	0.8	94.8	95.0
	control + GA	1.1	0.5	2.3	3.1	1.1	0.9	95.5	95.5
	NaOH (0.05 N)	1.3	1.6	2.6	3.9	1.1	1.1	95.0	93.4
	NaOH (0.05 N) + GA	1.3	1.8	3.7	3.5	1.1	1.0	93.9	93.7
5	control	0.9	0.5	3.5	4.8	2.0	2.0	93.6	92.7
	control + GA	1.1	0.6	3.6	3.7	2.3	1.7	93.0	94.0
	NaOH (0.05 N)	1.3	1.7	4.0	5.1	2.0	2.3	92.7	90.9
	NaOH (0.05 N) + GA	1.4	1.8	4.8	4.9	2.4	2.1	91.4	91.2
7	control	0.9	0.5	8.0	7.4	2.5	2.3	88.6	89.8
	control + GA	1.1	0.6	6.8	6.5	2.6	2.5	89.5	90.4
	NaOH (0.05 N)	1.3	1.6	6.4	8.8	2.4	3.3	89.9	86.3
	NaOH (0.05 N) + GA	1.3	1.8	7.4	8.6	2.6	3.2	88.7	86.4

Table IV. Effects of Malting Treatments on Grain Weight, Protein, and Starch in Corn Malts

germination, days	treatment	hL wt, kg		1000-kernel wt, g		protein ($N \times 6.25$), %		starch, %	
		MS1	Vijay	MS1	Vijay	MS1	Vijay	MS1	Vijay
0	ungerminated	70.7	64.8	185.5	173.3	9.6	9.2	75.5	74.5
3	control	60.4	63.6	184.2	169.8	9.7	9.1	74.1	72.4
	control + GA	62.0	60.0	185.1	170.6	9.5	9.1	73.5	72.2
	NaOH (0.05 N)	59.4	61.9	185.5	168.6	10.0	8.2	70.8	68.6
	NaOH (0.05 N) + GA	58.8	59.8	178.7	168.5	9.3	8.0	69.1	67.8
5	control	55.6	56.6	175.5	164.4	9.5	9.0	69.0	68.3
	control + GA	56.6	57.6	174.7	168.6	10.0	9.2	70.0	69.6
	NaOH (0.05 N)	54.6	54.4	180.9	162.3	10.2	8.8	64.0	63.7
	NaOH (0.05 N) + GA	54.0	50.9	174.8	168.5	9.6	8.7	66.7	66.5
7	control	49.2	50.2	164.6	162.9	9.9	9.5	63.5	60.0
	control + GA	49.5	47.5	172.6	164.1	9.8	9.0	61.0	59.9
	NaOH (0.05 N)	50.7	48.7	177.1	158.7	9.8	10.0	64.7	63.3
	NaOH (0.05 N) + GA	51.1	50.9	167.8	158.8	10.1	10.4	60.6	59.1

Table V. Effects of Malting Treatments on the Amylolytic and Proteolytic Activities of Corn Malts

germination, days	treatment	DP,[a] °L		AA,[b] SKB/g		PA,[c] mg of N/100 g	
		MS1	Vijay	MS1	Vijay	MS1	Vijay
3	control	11	7	26.7	24.2	48.9	43.7
	control + GA	11	10	39.2	31.3	79.5	86.1
	NaOH (0.05 N)	11	10	40.4	29.1	45.8	40.7
	NaOH (0.05 N) + GA	13	10	53.5	43.0	63.3	56.2
5	control	16	15	75.0	50.3	55.8	48.1
	control + GA	18	16	78.3	60.0	103.0	104.3
	NaOH (0.05 N)	18	17	82.9	77.9	84.7	66.5
	NaOH (0.05 N) + GA	18	17	91.2	83.5	111.7	88.0
7	control	23	19	75.8	62.5	51.4	41.9
	control + GA	25	19	84.1	64.2	93.8	76.9
	NaOH (0.05 N)	24	26	97.7	85.8	78.7	61.7
	NaOH (0.05 N) + GA	25	28	100.2	92.5	83.1	82.4

[a] Diastatic power. [b] α-Amylase activity. [c] Proteolytic activity.

Table VI. Effects of Malting Treatments on Quality of Worts

germination, days	treatment	soluble N, %		RS[a] as maltose, %		color, TU[b]				extract, %		KI[c]	
						MS1		Vijay					
		MS1	Vijay	MS1	Vijay	O	Y	O	Y	MS1	Vijay	MS1	Vijay
3	control	0.49	0.37	2.3	1.9	0.9	0.9	0.5	0.4	50.0	45.5	31.6	25.3
	control + GA	0.54	0.47	2.3	1.9	1.0	0.8	0.2	0.4	52.8	49.7	35.8	32.4
	NaOH (0.05 N)	0.58	0.43	2.2	2.2	0.7	0.9	0.9	1.0	52.3	47.9	36.3	32.8
	NaOH (0.05 N) + GA	0.63	0.57	2.4	2.2	0.9	1.7	0.9	1.1	56.3	56.2	42.3	44.9
5	control	0.73	0.53	3.1	2.6	2.0	4.0	1.8	3.0	64.0	57.7	48.3	36.8
	control + GA	0.81	0.68	2.9	2.5	2.2	6.6	0.8	1.1	67.9	59.4	50.3	46.3
	NaOH (0.05 N)	0.78	0.65	2.8	2.6	2.4	4.3	2.0	4.0	64.6	66.9	47.6	48.9
	NaOH (0.05 N) + GA	0.79	0.69	3.0	3.1	2.1	5.6	2.9	6.1	65.7	71.4	51.6	49.4
7	control	0.81	0.67	3.2	2.8	3.8	16.2	3.7	8.2	70.0	62.7	50.9	44.1
	control + GA	0.86	0.76	3.1	2.6	3.3	11.6	–	–	71.1	63.7	54.8	52.8
	NaOH (0.05 N)	0.89	0.79	3.0	3.0	3.9	15.9	2.0	4.8	69.1	69.0	56.7	49.4
	NaOH (0.05 N) + GA	0.93	0.84	3.3	3.3	3.5	12.3	3.1	6.9	72.4	73.7	57.8	50.6

[a] Reducing sugar. [b] Tintometer units. [c] Kolbach index.

78 to 166 and 94 to 245 °L, respectively. Extending the germination of corn to 7 days increased the DP marginally. Alkali pretreatment followed by GA application increased considerably the α-amylase activity of 5-day malts as compared to that of 3-day malts. The response of MS1 to GA was higher than that of Vijay. Alkali pretreatment with and without GA produced highest α-amylase activity in the 7-day malts. Overall, MS1 corn showed superior α-amylase potential than Vijay. A considerable increase in the proteolytic activity of the malts occurred to GA and extended germination.

Wort Quality. The worts were clear and filtered normally. The conversion times were interpreted with caution because of tiny starch granules in the unfiltered mash persistently staining blue with iodine solution. Taking the mash to higher temperature for gelatinization followed by incorporation of active barley malt and combined mashing of corn and barley malts failed to dextrinize the resistant starch granules. The presence of starch granules resistant to dextrinization remains unexplained as this type of behavior has not been reported earlier in the literature. Conversion of susceptible corn starch occurred normally but for the artifact of the iodine staining of the resistant starch granules. Soluble N in the worts increased with germination but more so when GA was applied as such than in conjunction with alkali pretreatment (Table VI). Worts of Vijay malt contained less soluble N than the corresponding MS1 worts. Reducing sugars in the worts increased as germination was extended. Alkali pretreatment and GA apparently had little effect on the reducing sugars in the wort of either variety. The pH of the worts decreased with germination. The buffer index, indicative of acidity, was lower for the worts of Vijay subjected to alkali pretreatment as compared to that of the control. Worts of GA malts showed higher buffering capacity than the controls, presumably due to solubilized proteins. The worts of white corn malt appeared brighter and decidedly more yellowish in color than the corresponding 5- and 7-day malts of the yellow variety.

The extent of modification in corn malts as shown by the Kolbach index (KI) values (Table VI) largely depended on the variety, length of germination, and GA application. Alkali pretreatment and GA caused greater modification in the malts than in the controls with and without GA.

The percentage of extracts of 3-day malts of Vijay and MS1 increased from 45.5 to 62.7 and 50.0 to 70.0, respectively, when germinated for 7 days. Application of the GA increased the yield of MS1 extract more than that of Vijay. The increase in the percentage extract of 5- and 7-day malts of Vijay pretreated with alkali and GA was more than that of MS1 malt. The worts on concentration produced light-colored syrups with typical malty flavor characteristic of barley malt syrups. The results showed that factors such as variety, extent of germination, alkali pretreatment, and GA are important for obtaining corn malt of improved quality as described.

Registry No. GA, 77-06-5; α-amylase, 9000-90-2; starch, 9005-25-8; protease, 9001-92-7.

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