Exogenous Gibberellic Acid: Some Observations on The Mass Balance Barley-Malt-Beer in Terms of Fermentable Extract

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INTRODUCTION

During germination, barley grain synthesizes different enzymes that contribute to endosperm degradation. Most of these enzymes are triggered by gibberellic acid (GA_3), a hormone naturally released by the germinating embryo [1,2]. Early studies showed that the exogenous addition of gibberellin stimulated barley germination and amylase synthesis. As a consequence, several experiments with GA_3 were carried out during the second half of the 20th century, and the use of this hormone in the malting industry increased substantially. Nowadays, several malt-houses, when allowed by costumers, add small amounts of GA_3 at initial stages of malting in order to accelerate germination and, additionally, improve malt quality in terms of malt extract, soluble protein, and fermentability [1,2,3]. Due to the considerable increase of malt soluble protein when GA_3 is used, as well as some contrasting reports on malting loses and fermentability, the objective of this study was to evaluate the mass balance barley-malt-beer in terms of fermentable matter.

MATERIALS AND METHODS

- Two two-rowed malting barley varieties with different quality (Table 1). Only plump kernels were malted (i.e. those retained on sieve 6/64 x 3/4 in.). Both skinned and broken kernels were removed before malting.
- Two GA_3 doses (0.25 and 0.50 mg kg^{-1} of barley) added during steeping. Each GA_3 treatment was malted separately with Control samples included.
- 45% germination moisture. 120h steeping + germination time.

- Mass balance was first performed among malts (with no malting loses considered, Table 3), and from barley to malt to fermented wort (Table 4).

Table 1. Malt quality of malting barley samples used in GA_3 experiments.

Parameter[1]	AC Metcalfe	Prunella
ML (% d.b.)	11.09±0.37	8.19±0.94
TP (% d.b.)	10.97±0.23	11.20±0.29
HWE (% d.b.)	80.56±0.14	78.24±0.60
DP (°ASBC d.b.)	136±7.71	81±3.45
AA ($D.U._{20°C}$ d.b.)	122±7.78	43±5.04
WV (cp.)	1.48±0.02	1.45±0.03
SP (% d.b.)	4.60±0.09	3.17±0.25
FAN (mg L^{-1})	139±15.93	80±13.64
KI (% S/T d.b.)	41.91±1.51	28.38±2.78
RDF (%)	82.82±0.90	85.42±0.71

[1]ML: malting loses; d.b.: dry basis; TP: malt total protein; HWE: hot water extract; DP: diastatic power; AA: Alpha amylase; WV: wort viscosity; SP: soluble protein; FAN: free amino nitrogen; KI: Kolbach index; RDF: real degree of fermentation.

RESULTS AND DISCUSSION

As expected, GA_3 has significant effects on malt quality (Table 2) when it is used at low concentrations (i.e. 0.25 mg kg^{-1}). The use of this hormone in higher amounts, as it was pointed out in early studies, has no considerable benefits. Moreover, some parameters such as malting loses, alpha amylase, and wort color show disproportionate increases.

Table 2. Combined malt quality of two two-rowed malting barley samples as affected by two GA_3 treatments.

Parameter	Malting set 1		Malting set 2	
	Control	GA_3 0.25	Control	GA_3 0.50
ML (% d.b.)	9.08a	9.59b	10.20a	11.22b
TP (% d.b.)	11.24a	11.35a	10.93a	10.85a
HWE (% d.b.)	79.15a	80.18b	79.65a	80.86b
DP (°ASBC d.b.)	110a	115a	107a	111b
AA ($D.U._{20°C}$ d.b.)	81.8a	94.2b	82.7a	107.4b
WV (cp.)	1.47a	1.48a	1.45a	1.55b
WC (°SRM)	1.94a	2.38b	1.93a	3.09b
SP (% d.b.)	3.74a	4.41b	4.03a	4.44b
FAN (mg L^{-1})	98a	122b	122a	167b
WBG (mg L^{-1})	237a	89b	131a	73b
KI (% S/T d.b.)	33.3a	38.9b	36.9a	39.8b
RDF (%)	84.7a	84.4a	83.5a	81.2b
FC+/FC (%)	86.2a	85.1b	83.0a	81.5b

[1]ML: malting loses; d.b.: dry basis; TP: malt total protein; HWE: hot water extract; DP: diastatic power; AA: Alpha amylase; WV: wort viscosity; WC: wort color; SP: soluble protein; FAN: free amino nitrogen; WBG: beta glucan in wort; KI: Kolbach index; RDF: real degree of fermentation;FC+/FC: (maltose+fructose+glucose)/(maltose+fructose+glucose+maltotriose).

When Control and GA_3 malts were compared from a mass balance perspective (Table 3), it was observed that GA_3 malts (at 0.25 mg kg^{-1} of barley) have more fermentable matter (RDF of MSS) than control malts as it has been broadly reported. However, the higher level of GA_3 showed the opposite which was mainly due to their significantly lower RDF values. The reduction of RDF was related to the increase of maltotriose, a partly fermentable carbohydrate, which resulted in the reduction of the ratio FC+/FC [(maltose+glucose+fructose) / (maltose+glucose+fructose+maltotriose)] in wort; also, this ratio was lower when GA_3 was used at 0.50 mg kg^{-1} of barley. The higher amounts of maltotriose could be linked to the excess of AA that is synthesized when GA_3 is used (Table 2). It is possible that this enzyme, during the 1-hr mashing time for HWE, generates more substrate than beta amylase can digest in the set time.

Table 3. Mass balance (in kg, from malt to fermented wort) between checks and GA_3 malts according malt quality values from Table 2. The analysis considers 1000kg of malt with 5% grain moisture. Each malting set was carried out in different dates.

Variable[1]	Malting set 1		Malting set 2	
	Check	GA_3 0.25	Check	GA_3 0.50
Malt weight	1000	1000	1000	1000
Malt dry matter	950	950	950	950
MSS (i.e. extract)	751.93	761.71	756.68	768.17
SP	35.53	41.90	38.29	42.18
RDF of MSS	637.04	642.58	631.98	624.14
MSS-SP	716.40	719.81	718.40	725.99
RDF of (MSS-SP)	606.93	607.23	600.01	589.87

[1]MSS: malt soluble solids after mashing; SP: weight of protein weight in malt soluble solids; RDF of MSS: weight of fermentable matter in malt soluble solids; MSS-SP: malt soluble solids – soluble protein (i.e. solids that can already, and partially, be converted into ethanol); RDF of (MSS-SP): fermentable matter of nonprotein malt soluble solids (assuming same RDF).

On the other hand, if malting loses are included in mass balance comparisons, GA_3 malts (at 0.25 mg kg^{-1} of barley) still show higher fermentable matter (RDF of MSS) than Control malts. However, now both GA_3 treatments have less nonprotein fermentable matter, or 'RDF of (MSS-SP)', than Control malts (Table 4). This is an important outcome since the nonprotein fraction of malt extract (with >99% carbohydrates) is the one that provides the substrate for ethanol synthesis. The variable 'RDF of (MSS-SP)' was calculated considering the same RDF value observed for MSS. This assumption is based on the fact that the weight of FAN utilized during fermentation is <0.2% of MSS.

Table 4. Mass balance (in kg, from barley to fermented wort) between checks and GA_3 malts according malt quality values from Table 2. The analysis considers 1000kg of barley with 12% grain moisture. Each malting set was carried out in different dates.

Variable	Malting set 1		Malting set 2	
	Check	GA_3 0.25	Check	GA_3 0.50
Barley weight	1000	1000	1000	1000
Barley dry matter	880	880	880	880
Malting loses	79.90	84.39	89.76	98.74
Malt dry matter	800.10	795.61	790.24	781.26
MSS (i.e. extract)	633.28	637.92	629.43	631.73
SP	29.92	35.09	31.85	34.69
RDF of MSS	536.51	538.15	525.70	513.28
MSS-SP	603.36	602.83	597.58	597.04
RDF of (MSS-SP)	511.17	508.55	499.10	485.10

[1]MSS: malt soluble solids after mashing; SP: weight of protein in malt soluble solids; RDF of MSS: weight of fermentable matter in malt soluble solids; MSS-SP: malt soluble solids – soluble protein (i.e. solids that can already, and partially, be converted into ethanol); RDF of (MSS-SP): fermentable matter of nonprotein malt soluble solids (assuming same RDF).

CONCLUSIONS

The use of GA_3 during malting of barley still provides some advantages such as the increase of FAN or the reduction of WBG. Although GA_3 increases HWE, the increase of SP and the reduction of RDF result in lower nonprotein fractions in wort when compared to Control malts. Considering that the major advantage of GA_3 is accelerating barley germination, these findings suggest the study of partly-modified malts (which is undergoing), to understand the real advantages of exogenous GA_3 in terms of fermentable extract, from barley to beer.

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