

Industrial production of gluten-free (barley) malt beers by use of selected processes for beer clarification



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Gluten and gluten-free

Gluten

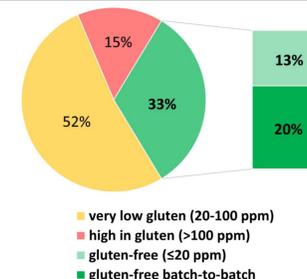
- Storage proteins found in wheat, barley and rye
- Rich in the amino acids glutamine (35-37%) and proline (17-23%)
- Trigger an immune-mediated mucosal villous atrophy in 1-3% of the world population genetically predisposed to coeliac disease

Gluten-free (EC No 41/2009, 2009)

- ≤ 20 ppm gluten
- Gluten-free products belong to two categories:
 - Products made from non-gluten-containing grain(s)
 - Products made from gluten-containing grain(s) but processed to remove the gluten to the gluten-free ≤ 20 ppm safe level

Gluten in beer

- Mainly originate from malted barley
- Malting and mashing → hydrolysis of gluten
- Brewing and clarification steps → Removal of gluten



Yet, **only 20%** of the commercial beers tested were **gluten-free** in a **reproducible manner** (Fig. 1) [1].

Figure 1. Distribution of gluten concentrations in Belgian barley malt beers ($n=153$; n corresponds to 51 different beers from three different production batches)

Gluten (poly)peptide quantitative analysis by competitive R5-ELISA (R7021, R-Biopharm, Germany)

Thus, gluten-free malt beers are a **market opportunity** for brewers.

Beer clarification techniques and how they can be used as gluten-minimization techniques

Colloidal haze

- Caused by haze-forming polyphenols cross-linked to proline-rich regions on haze-forming proteins (e.g. gluten) by hydrogen bonds (Siebert's model, Fig. 2)
- Problem: Risk of colloidal instability of the beer
- Solution: Removal of haze-forming proteins and polyphenols from wort and (green) beer
 - clarification techniques (e.g. centrifugation)
 - the use of clarification process aids, so-called beer stabilizers

Beer stabilizers

- Adsorb or degrade haze-forming polyphenols and/or proteins (Fig. 2)

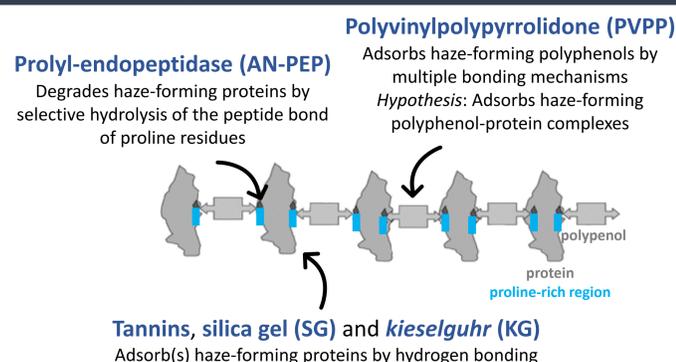


Figure 2. Siebert's model for protein-polyphenol interaction in colloidal haze and a selection of beer stabilizers and their mode-of-action to remove haze precursors (e.g. gluten)

Aim and Experimental design [2]

Study of the gluten-minimizing effect of combined processes for beer clarification and their implementation in pilot-scale and industrial-scale production of 100% barley malt beers.

	Malting	Mashing	Mash clarification	Cooking	Wort clarification	Fermentation	Maturation	Beer clarification	
Exp. 1 (0.7-hL)	All-barley malt (OE 16°P)	+ Tannins *	Lauter tun	+ Tannins *	Whirlpool	+ AN-PEP * Ferm. @ 22°C	/	/	Alc. 7.5% (V/V%)
Exp. 2 (30-hL)	All-barley malt (OE 15°P)	-	Mash filter	-	Whirlpool	+ AN-PEP Ferm. @ 22°C	-	Centrifuge	Alc. 6% (V/V%)
Exp. 3 (3,000-hL)	All-barley malt (OE 11°P)	-	Lauter tun	-	Whirlpool	+ AN-PEP * Ferm. @ 12°C	+ SG	Candle filtration + KG, + PVPP	Alc. 5% (V/V%)

OE: Original extract, AN-PEP: Prolyl-endopeptidase from *Aspergillus niger*, SG: Silica gel, KG: Kieselguhr, PVPP: Polyvinylpolypyrrolidone, *: Treatments different from the untreated reference

Results and Conclusion [2]

Gluten levels

Beer stabilizers can significantly reduce the gluten concentration to 'low gluten' (≤ 100 ppm) and **gluten-free (≤ 20 ppm)** levels (Table I).

Table I. Comparison of gluten concentrations (ppm) in untreated reference to treated green and final beers

Gluten (poly)peptide quantitative analysis by competitive R5-ELISA (R7021, R-Biopharm, Germany)

Exp.	Reference		Treated	
	Green beer	Final beer	Green beer	Final beer
1	309 ± 25	n.d.	46 ± 1	n.d.
2	70 ± 2 *	n.d.	< 10	< 10
3	292 ± 12	58 ± 7	119 ± 7	< 10

n.d.: not determined

* Gluten conc. (ppm) in wort at the start of fermentation

The use of prolyl-endopeptidase from *Aspergillus niger* (AN-PEP) alone didn't suffice to make the green beer gluten-free by the end of the fermentation (@ 12°C), the additional use of silica gel was required to lower the remaining gluten levels to below the gluten-free threshold. (Temperature optimum for AN-PEP is 50°C.)

Quality and sensory attributes

The use of beer stabilizers in the production of gluten-free malt beers has:

- no effect on beer colour, foam stability, taste and aroma
- Resulted in **improved beer clarity** (Fig. 3)

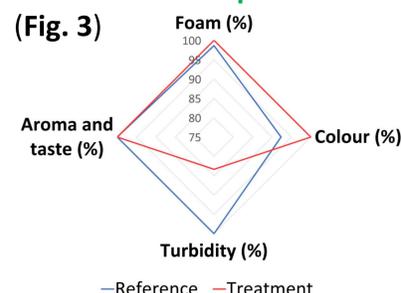


Figure 3. Comparison of normalized (%) beer quality (foam stability, beer colour, beer turbidity) and sensory (aroma and taste) attributes in untreated reference to treated final beers.

Example Exp. 3

Reproducibility industrial production

Gluten-free malt beers batch-to-batch ($n=14$; n corresponds to different production batches monitored of Exp. 2)

[1] Watson et al. (2018) Variation in gluten protein and peptide concentrations in Belgian barley malt beers, *J. Inst. Brew.* 124(2), 148-157.

[2] Watson et al. (2018, under minor revisions) Applicability of different brewhouse technologies and gluten-minimization treatments for the production of gluten-free (barley) malt beers: pilot- to industrial-scale, *J. Food Eng.*