

# BEER FROM 100% BARLEY

STEN AASTRUP, NOVOZYMES A/S. E-MAIL: SAAU@NOVOZYMES.COM

In September 2009, a new product, Novozymes Ondea® Pro, was launched at Drinktec in Munich. Ondea Pro allows high-quality beer to be made directly from barley. The first commercial beer made with Ondea Pro, Clim8 from the Danish brewery Harboe, was also launched at Drinktec, and the taste evaluation carried out by the many experienced brewers and beer lovers demonstrated that great-tasting lager does not require the use of malt – barley and Ondea Pro can do the job.

Nine months have passed since Drinktec, and it has certainly been a busy time for Novozymes discussing and trying out this new concept at breweries around the world. Industrial-scale trials have been carried out at more than 20 breweries, and regular production has already been established in various parts of the world. New brands have popped up, and more will follow. In all cases, the quality of the 100% barley beer has impressed the brewers. ‘It’s surprisingly good’ and ‘tastes like normal beer’ are two of the most frequently heard comments. The reaction when the Danish Brewers’ Guild visited Novozymes on 21 April, 2010, and tasted the 100% barley beer was no exception, and after our presentation of the Ondea Pro

concept, the general opinion was that ‘this is a true revolution in the brewing industry’. As with any other revolution, not everyone agrees with the ‘new way’, so 100% barley brewing has, naturally, generated a lot of discussion on, among other things, the actual definition of beer. There is no doubt that the ‘new way’ has also generated a lot of interest, and we at Novozymes believe that in the future this will just be one of many ways to make beer. The 100% barley beer can stand alone or be blended in any ratio with traditionally made beer. This paper briefly describes traditional barley brewing and the development toward 100% barley brewing. The important differences between traditional barley brewing and brewing

with Ondea Pro are set out. Novozymes’ experiences to date with industrially produced 100% barley beers are presented. The correct use of Ondea Pro based on our present experience is outlined, as well as the savings and benefits that can be achieved using this new concept for beer production.

## BARLEY AND COMMERCIAL ENZYMES

Barley and commercial enzymes are not a new idea. Barley has been part of beer recipes for many years. And commercial enzymes have routinely been used as a supplement to malt enzymes to ensure trouble-free brewhouse performance when using undermodified malt or barley/malt blends. Figure 1 gives examples of barley usage in traditional barley brewing. The idea of regarding malting and mashing

EXAMPLES OF GRIST COMPOSITIONS AND ENZYME APPLICATION INVOLVING BARLEY 2000-2008					
Grist composition	Daily production			Experimental brews	
	1	2	3	4	5
Malt, %	35	38	70	50	30
Barley, %	35	34	30	50	70
Corn grits, %	30	28	–	–	–
Applied enzymes (ppm):					
Ceremix® 2 XL, Plus MG	750*	1,000*	450&	300&	
Ultraflo® L, Max	200*	200&	150&	200&	250&
Termamyl® 120 L, SC	600#	400#	130&		210&
Neutrase® 0.8 L	300*				700&
Attenuzyme®			130&	150&	210&

Base for enzyme quantity calculations: \*on barley; #on adjuncts; &on grist

Fig. 1. Traditional barley brewing with standard commercial enzymes: 1-3: Use of standard brewing enzymes in daily production of beer, 4-5: Experimental brews for higher barley inclusion.

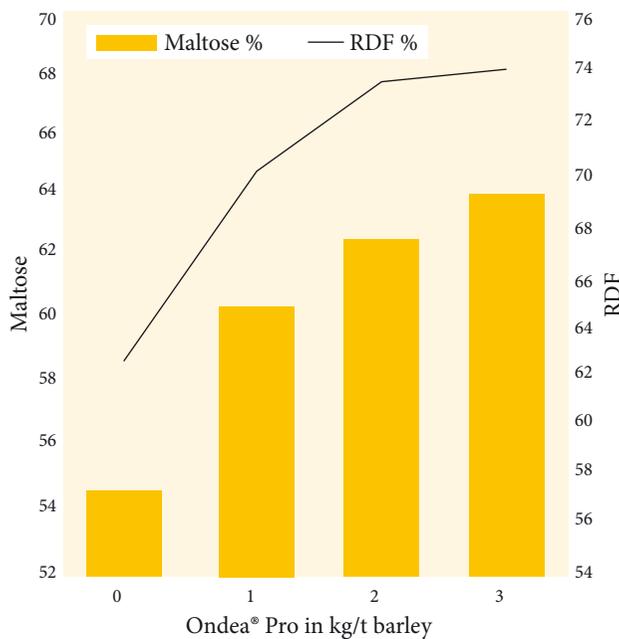


Fig. 2. Synergy between Novozymes Ondea® Pro and barley  $\beta$ -amylase.

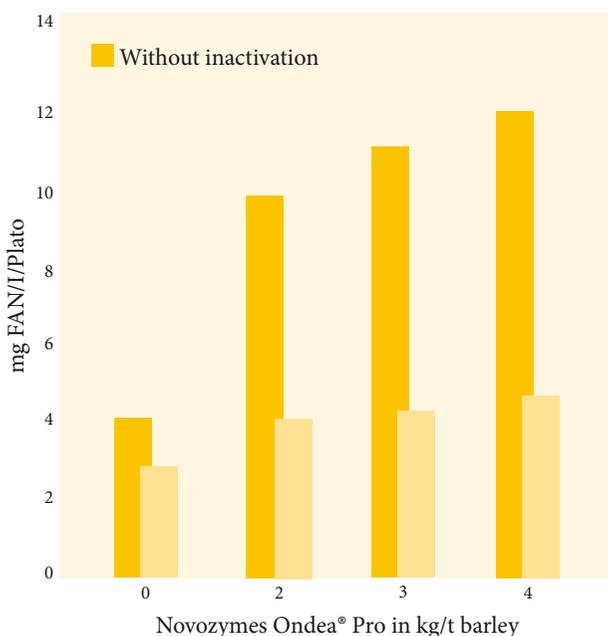


Fig. 3. Synergy between Novozymes Ondea® Pro and barley exoprotease.

SUGAR PROFILE	
Glucose	< 8%
Fructose	< 2%
Maltose	> 55%
Maltotriose	< 15%
Dextrins (DP4+)	< 20%

Fig. 4. Typical wort made with 100% barley and Novozymes Ondea® Pro, resulting in high maltose and low glucose values.

as one event transforming barley directly into fermentable wort is not new either. At the EBC Congress in Estoril in 1971, Nielsen (4) presented trials showing that beer can be made from 100% barley and commercial enzymes. The present author presented the use of very undermodified malt in combination with commercial enzymes at MBAA in Keystone in 1999 (1). In 2003, Hannemann published further details on brewing with undermodified malt as well as successful malt-free barley brewing at Kenyan breweries (5). In 2001, Bamforth (2) presented his 'new brewing paradigm', making beer from barley endosperm and commercial enzymes, an idea that was further developed in 2009 (3).

Ondea brewing more than fulfils the visions of Nielsen and Bamforth, although it does not go as far as Bamforth, who assumed that all the enzymes involved are commercial. Ondea brewing is based on a synergy between the barley enzymes and the commercial enzymes, resulting in a wort performing just like malt-based wort.

#### Traditional barley brewing versus Ondea brewing

In traditional barley brewing, barley is used as an adjunct, mainly as a starch source:

- In Ondea brewing, barley is used as an active enzyme source together with Ondea Pro, and as a supplier of all the components needed for a fully fermentable wort that performs similarly to a malt-derived wort
- In Ondea brewing, the barley enzymes work in synergy with the Ondea Pro enzymes
  - Barley  $\beta$ -amylases for degradation of starch to maltose (Fig. 2)
  - Barley exo-proteases for free amino nitrogen (FAN) formation (Fig. 3)

In traditional barley brewing, it is possible to come very close to 100% barley brewing using conventional enzymes. However, the taste and texture of these beers is significantly different from standard lager-type beer, not least because the worts for these beers are 100% glucose based. It has also proven possible to make more maltose-based wort with conventional enzymes, but these worts have very low fermentability and very high turbidity. Wort produced with Ondea Pro results in a maltose-based wort (Fig. 4) that shows higher maltose values and lower glucose values compared with malt-based worts. Furthermore, the fermentability and turbidity are normal.

#### Clim8 – The very first commercial beer brand based on Ondea Pro

Production data from Harboe showed very little deviation from their normal production using all-malt infusion mashing with →

SENSORY ANALYSIS (OUTPUT VALUES)						
Sample feature	F0 (B0047TK) start value after filling and transport	F20 (B0048TK) start value after filling and transport	F40 (B0049TK) start value after filling and transport	F60 (B0050TK) start value after filling and transport	F80 (B0051TK) start value after filling and transport	F100 (B0052TK) start value after filling and transport
<b>Aroma</b>	3.8	3.9	4.0	3.9	4.2	3.8
<b>Flavour</b>	3.7	3.8	3.8	3.7	3.7	3.6
<b>Pallatefulness</b>	3.8	4.1	3.9	3.9	3.8	3.8
<b>Sparkle/ carbonation</b>	3.9	4.3	4.2	4.2	4.2	4.1
<b>Bitterness</b>	3.9	3.9	3.9	3.8	3.9	4.0
<b>Comment</b>						

Source: TU Berlin – Prof. Dr.-Ing. Frank-Jürgen Methner, Thomas Kunz (030/45080123)

Fig. 5. Taste results for six beers showing high acceptance of 100% barley beer and 100% malt beer and different blends. The maximum score is 5. FO: 100% malt beer, F20: 20% barley + 80% malt beer, F40: 40% barley + 60% malt beer, F60: 60% barley + 40% malt beer, F80: 80% barley + 20% malt beer, F100: 100% barley beer.

MILLED BARLEY COMPARED TO MILLED MALT SPECIFICATION		
	Barley	Malt
Sieve 1	25-30%	(18%)
Sieve 2	15-20%	(8%)
Sieve 3	33-40%	(33%)
Sieve 4	10-15%	(21%)
Sieve 5	2-5%	(10%)
Bottom	8-12%	(11%)

Fig. 6. Sieving test for barley grist that has shown good performance with 100% barley brewing with Novozymes Ondea® Pro. Note the coarser grist compared with malt grist.

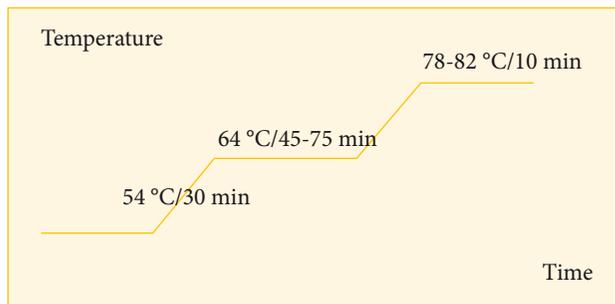


Fig. 7. Mashing profile for 100% barley brewing with Novozymes Ondea® Pro.

hammer milling and a Meura 2000 filter. The main differences per brew were:

- 11 tonnes of barley instead of 10 tonnes of malt
  - 10 per cent more barley than malt due to barley having a 10 per cent higher moisture content than malt
- 50 kWh more electricity for hammer milling due to the hardness of barley compared with malt
- 1 tonne less of water to ensure the same amount of dry matter in the mash

The taste evaluation of the final beer carried out at TU Berlin showed no significant difference in beer quality between 100% malt beers and 100% barley beers and blends (Fig. 5).

#### HOW TO USE ONDEA PRO

Based on our experience with 100% barley brewing so far, we have the following facts and recommendations for brewing with 100% barley and Ondea Pro.

#### The enzyme

Ondea Pro is a unique enzyme containing a viscosity-reducing component, a turbidity-reducing component, and components for yeast performance control as well as attenuation control to ensure the same trouble-free operation and yield as with malt.

- Usage recommendation:
  - Barley-to-water ratios in mashing: 1:2.2-1:3.5
  - Saccharification rest: 45-75 minutes
  - Target RDF: from 66% to above 70% (maltose wort)
  - Enzyme dosage: 1.5-2.5 kg/t barley

### The barley

- The barley must be food grade according to local regulations
  - The specifications must include requirements for contaminants such as mycotoxins and pesticide residues
  - Novozymes recommends maintaining the same level of quality control with barley for direct brewing as with barley for malt production
- It is not necessary to use spring barley that matches malting specifications
  - Special parameters for a successful malting process (e.g., germination energy, water sensitivity, the relationship between cytolytic and proteolytic degradation) are obsolete
- The endogenous enzymes (exopeptidases and  $\beta$ -amylase) of the barley must be active
- FAN correlates with the protein content. Up to 13 per cent protein has been successfully processed

The barley performance is checked using a barley quality test, which is a modified 'Congress mash' with Ondea Pro measuring turbidity, throughput, FAN, sugar profile, amino acids, viscosity,  $\beta$ -glucan, and pH.

### The milling

- Hammer mill
  - More energy (50-75% more)
  - Possibly more wear of hammers
- Roller mill
  - Husk and endosperm should be separated, and the husk must be protected
  - Coarser grist compared with malt
    - Six-roller mill to be preferred
    - With four-roller and two-roller mills, the grist will be coarser but processable
  - More frequent maintenance of rollers

The best lautering performance is experienced with a six-roller mill using coarser barley grist compared with malt grist (Fig. 6).

### The mashing

To ensure the activity of Ondea Pro and the important synergy between the barley enzymes and Ondea Pro, the correct mashing profile is extremely important (Fig. 7):

- Barley-to-water ratios: 1:2.2-1:3.5
  - Calculating with the higher moisture content of barley
- Ondea Pro added at mashing-in
  - Recommended pH 5.7-6.0 (no adjustment of pH in the mash kettle)
- Continuous stirring in the mash kettle
- Protease rest at 54 °C to ensure FAN
- Saccharification rest at 64 °C
  - Saccharification time (45-75minutes) impacted by RDF target and dosage of Ondea Pro
- Mashing-off may not be starch negative – no problem as it will be in lautering

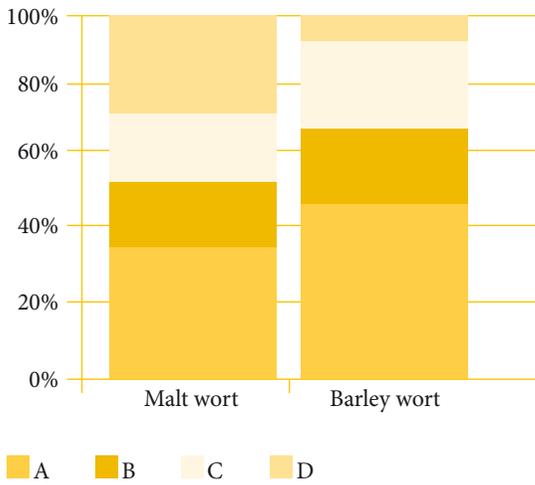
### Wort treatment

- Adjustment of wort pH < 5.2
  - Ensure right pH in final beer
- Less hops needed to reach similar bitterness perception to malt beer

### The wort separation

Using mash filters, no special actions need to be taken. The only issue is to make sure that the dry matter loading is the same as when using malt; that is, to take into consideration the moisture content of the barley.

When lautering the more coarse barley grist, the normal standard lauter programme can be used in terms of circulation time and lauter speed. But when carrying out your first trials with Ondea brewing, set the raking machine on 'hand' and do not allow the raking machine to destroy the cake. In fact, the machine should only work on the surface of the cake. After first wort collection, initiate one deep cut and make sure that at the end of the deep cut, the raking machine is back in the first position and again on 'hand'. For routine Ondea brewing, a separate specific automation programme is recommended. Optimisation of the lautering performance can ensure the desired washable extract. From our experience, we have spent grains analyses showing extractable extract of 0.5 per cent and washable extract of 1.2 per cent on average. →



<b>Group A - Fast absorption</b> Glutamic acid, Aspartic acid, Asparagine, Glutamine, Serine, Threonine, Lysine, Arginine
<b>Group B - Intermediate absorption</b> Valine, Methionine, Leucine, Isoleucine, Histidine
<b>Group C - Slow absorption</b> Glycine, Phenylalanine, Tyrosine, Tryptophan, Alanine
<b>Group D - Little or no absorption</b> Proline

Fig. 8. Left: Relative amino acid composition of malt and barley wort according to the amino acid fermentability groups. Right: The four amino acid fermentability groups.

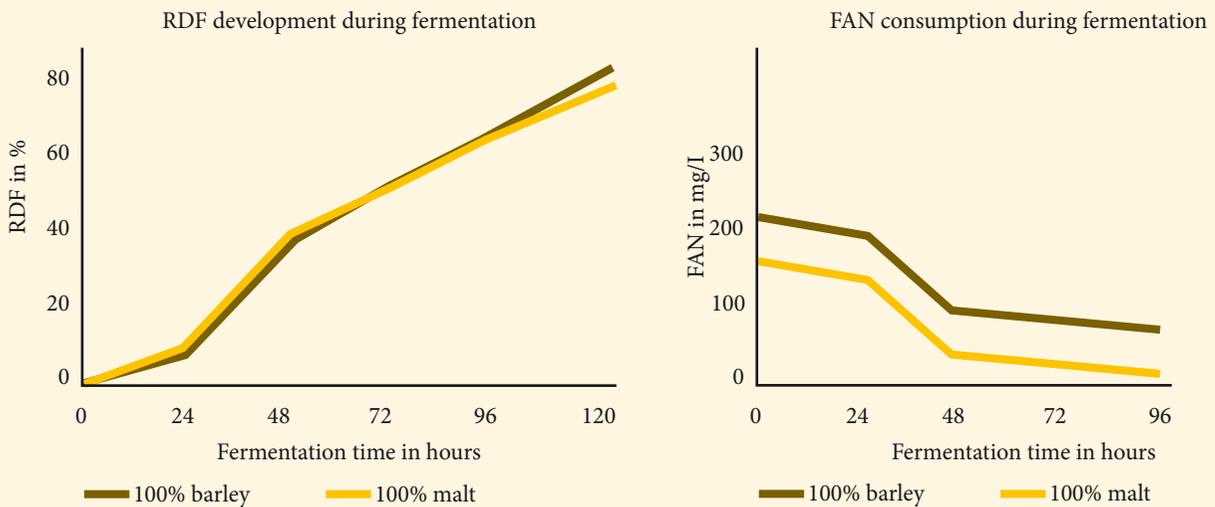


Fig. 9. Left: Fermentation performance of 100% barley wort and 100% malt wort. Right: FAN consumption during fermentation of 100% barley wort and 100% malt wort.

### Wort quality and fermentation performance

Barley wort produced with Ondea Pro has significantly higher amounts of fast-absorbing free amino acids (Fig. 8):

- The amino acids are often divided into four groups (6) according to their absorption by the yeast cell
- The amino acid profile of 100% barley wort differs from that of malt wort
- The barley wort contains relatively more of the easily fermentable amino acids and relatively less of the not-so-easily fermentable amino acids, especially proline
- This explains the good fermentability of the barley wort even though the FAN is lower than in malt wort
- Having an amino acid profile more suitable for the yeast leads to less amino acid-based Strecker aldehydes

100% barley wort shows comparable fermentation performance with less FAN (Figure 9):

- The FAN recommendations for malt brews are 120-220 mg/L (at 12 °P) or 10-18 mg/L/Plato
- The FAN from 100% barley wort is lower; 108-170 ml/L (at 12 °P) or 9-14 mg/L/Plato
- The barley worts have good fermentability
- This leads to less unfermented FAN at the end of the fermentation

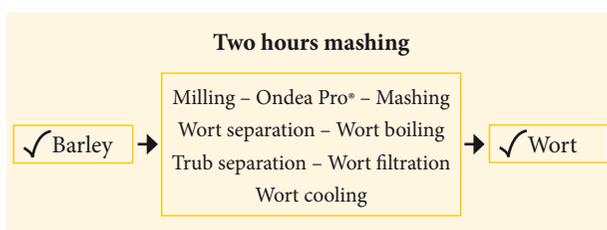


Fig. 10. Malting and mashing, one synergistic two-hour event.

### SAVINGS AND BENEFITS

Significant savings can be achieved by totally avoiding the malting process. The actual saving, however, will vary from process to process and from country to country depending on differences in barley, malt, and enzyme prices. Total savings in the range EUR 0.5-1.0/hl final beer are realistic depending on local conditions, mashing time, and barley, malt, and enzyme prices.

Decreased CO<sub>2</sub> emissions are also substantial. In the case of Clim8, an eight per cent CO<sub>2</sub> emissions, or 8 g CO<sub>2</sub>, reduction per 33-cl can were recorded.

### CONCLUSION

With Ondea Pro the vision of several scientists and far-sighted brewers has been realised – a great-tasting beer from 100% barley that cannot be distinguished from malt-based beer. Malting and mashing have become one event (Fig. 10) – one week's malting plus two hours' malt mashing has been replaced by two hours' barley mashing. ◻

### LITERATURE

1. Aastrup, S & Hannemann, W. 1999. MBAA Congress. Keystone
2. Bamforth, CW. 2001. *Brewer International*, 1 (2), 26–29
3. Bamforth, CW. 2009. *Journal of Cereal Science*, 50 (3), 305–414
4. Nielsen, EB. 1971. EBC Congress Proceedings, Estoril, 149–170
5. Hannemann, W. 2003. 9th Brazilian Congress of Brewery Science and Technology. Florianopolis
6. Jones, M & Pierce, J. 1964. *J. Inst. Brew.* 70:307–315