

100% BARLEY BREWING – EXPERIENCES WITH NOVOZYMES ONDEA®PRO

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ABSTRACT

Since the launch of Onda Pro – a dedicated enzyme for 100% barley brewing – more than 100 pilot- and industrial trials have been carried out. Regular production has already started in several breweries.

The key learnings from the first year will be presented, as well as perspectives for this new brewing concept.

Process data and taste evaluation data were collected from the Onda Pro brews and compared with similar data from reference brews and/or average data from the daily production.

The overall experience with Onda brewing so far has shown that it is possible to make great tasting beer based on 100% barley and Onda Pro using standard brewing equipment within the standard processing time. The key learnings include:

Specification for barley to be used for Onda brewing

Good, healthy barley with active enzymes (β -amylase and exoproteases) is important, but specifications can be broadened when compared with specifications for malting barley
A test for the evaluation of brewing performance with Onda Pro has been developed

Milling of barley

Milling for mash filters shows no problem
Milling for lauter tuns require optimization

Mashing

Specific mashing temperatures for protein rest and saccharification must be kept to provide the synergy between Onda Pro and the barley β -amylase and proteases
Continuous stirring at a fair speed during mashing is needed to deal with high viscosity

Wort quality

FAN composition is different in barley wort when compared with malt wort
Total FAN is dependent on the total protein content of the barley
Sugar profile is always maltose dominated, but varies according to mashing profile and barley quality

Fermentation

Fermentation profile is similar for barley wort and malt wort
Onda brewing with non-barley raw materials
Up to 30% adjunct has been shown to be processable
Extended mashing time to create more FAN might be required

Beer quality

Brewers and independent taste panels recognize that barley beer made with Onda Pro have similar scores as normal high quality beer, making it suitable for blending with conventional beers. Demonstrating that most types of beers can be made based on Onda brewing

The future of Onda brewing

So far brewers see Onda Pro as a new opportunity to make good tasting beer directly from barley, providing raw material savings as well as high flexibility in beer making and branding.



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INTRODUCTION

Novozymes Ondea® Pro, an enzyme product that converts raw barley directly into fermentable wort, was launched at Drinktec in September 2009. Since then brewing trials with Ondea Pro have been carried out all over the world – from US to China – from Iceland to Africa. The results have been very promising, giving many examples of high quality beer. Regular Ondea brewing is now a reality in several breweries.

Ondea brewing is certainly breakthrough technology for the production of beer. Re-inventing beer brewing is probably too much to say, but we at Novozymes truly believe that we are changing the world of brewing together with our customers. And doing it “together” is one of our key learnings so far. Being a new beer processing method, Ondea brewing requires full attention, enthusiasm and flexibility before it becomes routine. Sharing of knowledge and experiences is therefore essential to establish successful 100% barley brewing.

In this paper, Novozymes presents experiences and recommendations for industrial beer production based on up to 100% barley.

WHAT IS ONDEA PRO AND HOW AND WHY DOES IT WORK?

Ondea Pro is a unique enzyme product containing components to reduce viscosity and turbidity, combined with components to control both yeast performance and attenuation. Together, they can ensure the same trouble-free operation and yield as with malt.

In Ondea brewing, the barley enzymes work in synergy with the Ondea Pro enzymes

- Barley α -amylases for degradation of starch to maltose (Figure 1)
 - Higher values for maltose and Real Degree of Fermentation (RDF) with increased dosages of Ondea Pro
- Barley exo-proteases for Free Amino Nitrogen (FAN) formation (Figure 2)
 - More FAN with increased dosages of Ondea Pro only with active exoproteases

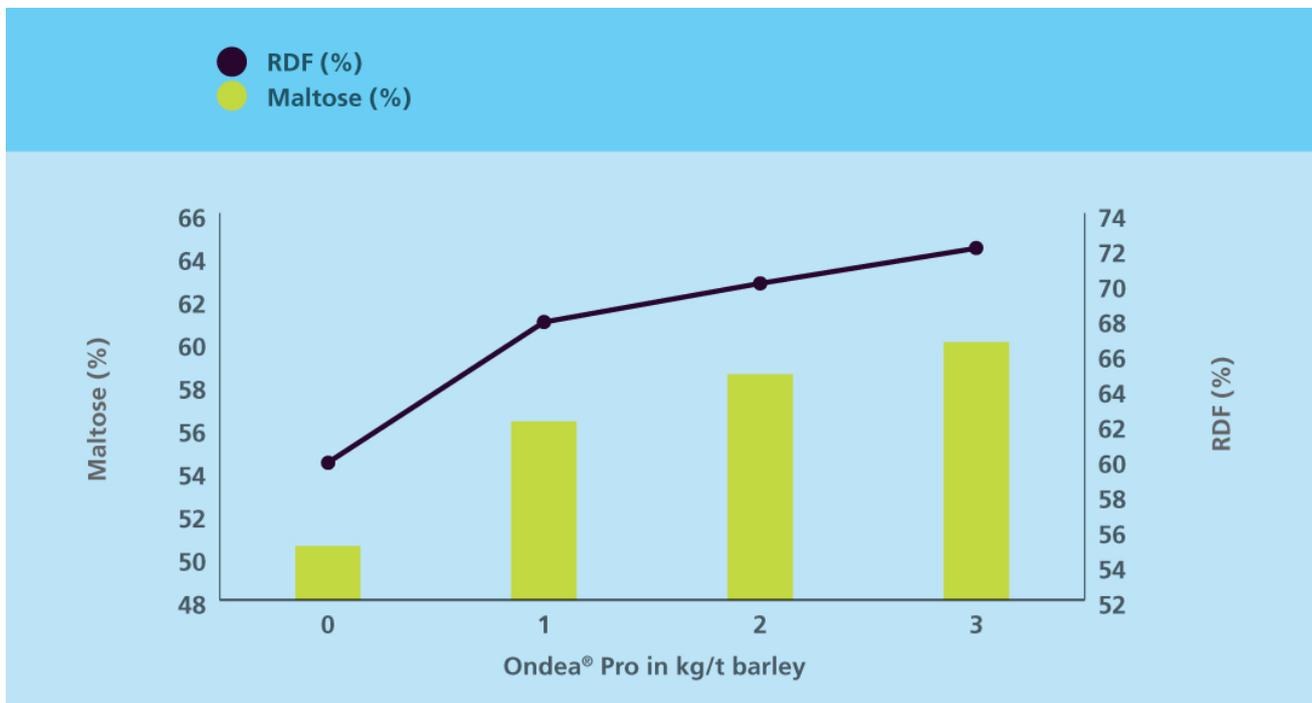


Figure 1: Synergy between Ondea Pro and barley α -amylase.

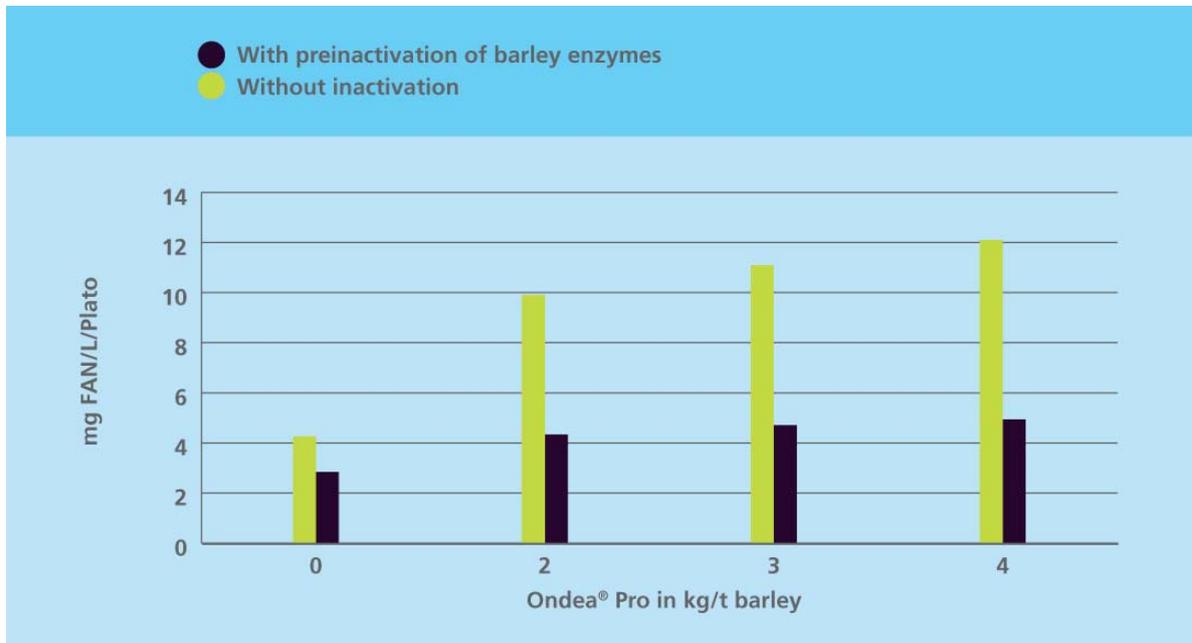


Figure 2: Synergy between Ondea Pro and barley exoproteases.

Ondea Pro simply supplies the essential mashing enzymes that in conventional brewing are produced during malting. Figure 3A shows the malt enzymes used during the degradation of cell walls (β -glucanase and xylanase), starch degradation (α -amylase, pullulanase and β -amylase), protein degradation (endo- and exoproteases), and lipid degradation (lipase), as well as the less wanted malt enzymes β -glucan solubilase and lipoxygenase, that give rise respectively to the additional liberation of β -glucan and papery off- flavours in beer. Figure 3B shows that the Ondea Pro enzymes substitute the “positive” enzymes produced during malting. The Ondea Pro enzymes are more heat-stable and more effective. So....

Ondea brewing can be considered as a fusion of malting and mashing

Produced during malting				Present in raw barley			
Enzyme	Optimal mashing pH	Optimal mashing temperature, °C	Inactivation temperature, °C	Enzyme	Optimal mashing pH	Optimal mashing temperature, °C	Inactivation temperature, °C
β -glucanase	4.5–5.0	40–50	40–55	β -amylase	5.4–5.6	60–65	70
β -glucan solubilase	4.6–4.9	62	75	α -amylase	5.6–5.8	70–75	80
Xylanase	5.0	45	50	Pullulanase	5.0–5.2	55–60	65–70
Endoprotease	5.0–5.2	50–60	70	Lipase	6.8	35–40	60
Exoprotease	5.2	50–60	70	Lipoxygenase	6.5	40	70

Figure 3A: Malt enzymes for the conventional production of a fully fermentable wort.

- Present in Ondea® Pro
- Present in raw barley

Enzyme	Optimal mashing pH	Optimal mashing temperature, °C	Inactivation temperature, °C	Enzyme	Optimal mashing pH	Optimal mashing temperature, °C	Inactivation temperature, °C
β-glucanase	4.0–5.8	65	75–80	β-amylase	5.4–5.6	60–65	70
β-glucan solubilase	4.6–4.9	62	75	α-amylase	5.2–5.5	70–90	95
Xylanase	5.0	65	75–80	Pullulanase	3.5–6.0	60–65	65–70
Endoprotease	6.0	40–50	70	Lipase	5.0–9.0	45–65	70
Exoprotease	5.2	50–60	70	Lipoxygenase	6.5	40	70

Figure 3B: Barley enzymes and Ondea Pro enzymes are sufficient to produce a fully fermentable wort.

ONDEA BREWING VERSUS CONVENTIONAL BREWING

From a helicopterview, it is not easy to see the difference:

- The resulting beer cannot be distinguished from conventionally brewed beer
- Any type of beer can be made based on Ondea brewing, exchanging malted barley with raw barley and Ondea Pro
- Standard brewing equipment and standard brewing procedures, including high gravity brewing and adjunct brewing, can be used for Ondea brewing
- Process challenges with Ondea brewing are similar to the ones known from conventional brewing

So it initially seems that the brewer has the same possibilities and challenges when using raw barley and Ondea Pro as when using malted barley.

A closer look demonstrates differences and important issues the brewer needs to become familiar with.

BARLEY QUALITY

The Ondea brewing concept allows the strict malting barley specifications to be broadened without damaging the final beer quality. Consequently, this allows the direct use of local crops, making beer production more sustainable. This benefit primarily arises as the Ondea Pro enzymes have superior activities and better heat stability than the malt enzymes, and due to the fact that the parameters necessary for a successful malting process (e.g. germination energy, water sensitivity, relationship between cytolytic and proteolytic degradation) are of less importance.

However, this does not mean that barley that is inferior in terms of food safety requirements can be processed. The synergy between Ondea Pro, the barley proteases, and barley α-amylase is essential, so barley grains with active enzymes are essential for successful brewing performance.

As a raw material for beer production, the barley also has to comply with the respective national and regional regulations concerning mycotoxins, pesticide residues, heavy metals, etc. and has to be free of foreign material such as stones, wood, and metal particles. Furthermore, a maximum of 4% of the barley must be below 2.2 mm in size.

The extract yield from barley is the same as the extract yield from malt derived from the same barley on a dry basis.

FAN correlates with the protein content. Up to 13% protein has been successfully processed.

The barley performance can be checked using a barley quality test, which is a modified “Congress mashing” with Ondea Pro, where turbidity, throughput, FAN, sugar profile, amino acids, viscosity, β -glucan, and pH are measured on the Congress wort.

A detailed description of barley requirements and the barley quality test can be downloaded from the Novozymes’ Customer Centre at www.novozymes.com.

Challenge: In some parts of the world it might be difficult to source barley of sufficient and guaranteed quality. So it is recommended to investigate how to obtain barley of the right quality as part of the business case for Ondea brewing.

BARLEY MILLING

When compared with malt, barley is significantly harder and has a higher initial water content. In order to ensure comparable performance, the mill needs some adjustments and a higher power uptake.

Mash filter: For use with a mash filter, a standard hammer milling procedure (with adjusted power uptake), or any comparable system such as a Dispax, is sufficient to ensure the perfect mash filtration. When cleaning the mash filter, spent grain fall-off from the filter sheet is most efficient when the dry matter load is comparable to malt.

Lauter tun: When using a lauter tun, the milling and resulting grist composition are critical for good lauter performance. Husk preservation is of great importance for effectively building up the filter bed. For better roller milling, it is recommended to use barley of homogeneous size > 2.2 mm.

Challenge: Two-, four- and six-roller mills have been used with success. Difficulties, however, have been experienced in some cases, resulting in extended lautering time and extract loss. So a reliable correlation between grist composition and lauter performance has to be established and adapted to the local conditions in the brewery. Novozymes continues to investigate this in collaboration with equipment suppliers and breweries.

MASHING

It is recommended that Ondea Pro is added at mashing-in, when one third of the grist has been added. The mashing-in temperature should be 50°C. For a successful mashing, it is essential to retain the temperature profile shown in Figure 4.

The synergy between the heat-sensitive proteases and α -amylase of the barley and Ondea Pro can fail if the temperatures are overshot. So be sure that the highest temperature at mashing-in and throughout the first 30 minutes (protein rest) does not exceed 54°C. Also ensure that the saccharification temperature does not exceed 64°C to support the performance of the heat-sensitive barley α -amylase.

The mashing pH should *not* be adjusted. The natural mashing pH of barley is normally > 5.7. The lowest acceptable pH is 5.6. A pH of higher than 5.9 should be avoided as it might cause high turbidity.

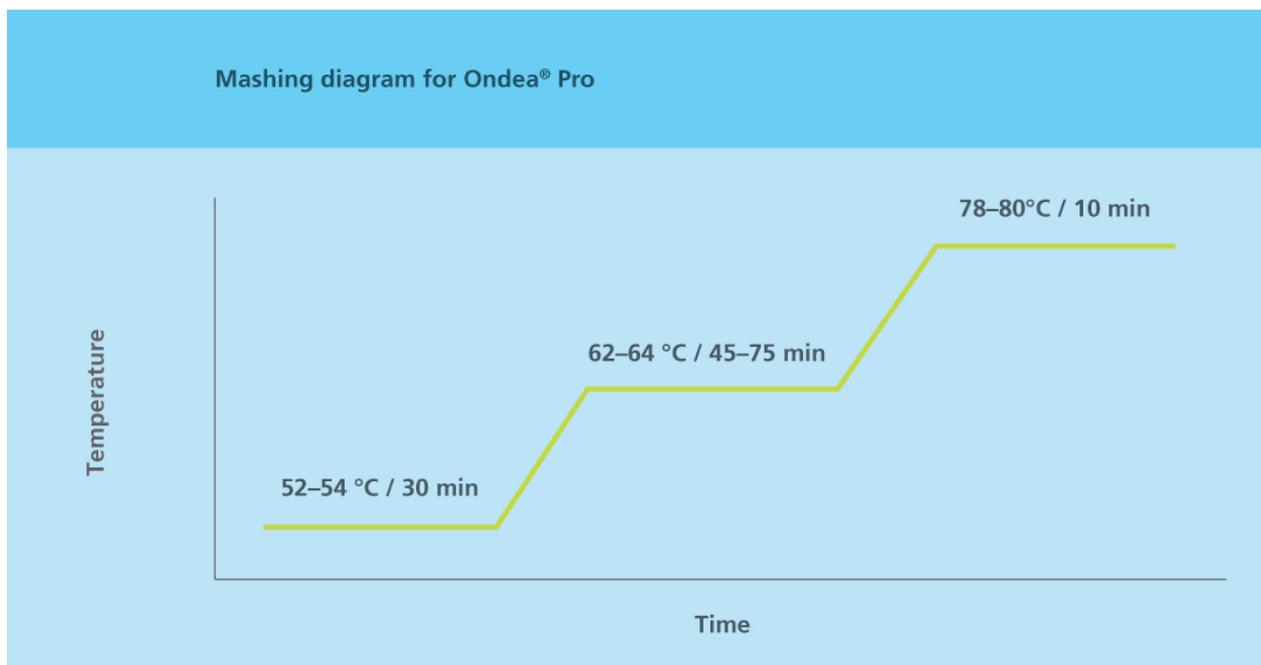


Figure 4: Simple infusion mashing profile for a 70% RDF target wort using a dosis of 2 kg Ondea Pro per ton barley.

The dosage and saccharification time at 62–64°C can be adjusted so as to achieve your desired production programme.

Continuous stirring is required throughout the mashing to prevent settling of the grist and ensure the effective action of the enzymes.

At the end of saccharification, the iodine test may be positive. Even at the end of mashing-off, the wort may not be completely iodine negative. There is, however, no need to extend the mashing-off time as the starch degrading enzymes are still active during wort separation. The final wort will always be iodine negative.

Challenge: Barley has a higher density when compared with malt, so make sure that the right transport system for the barley is in place.

Barley and water mix has a higher viscosity and is more sticky compared with malt and water mix, so make sure that the barley and water mix is not clotting in pipes or at mashing-in.

Wort Separation

When using a mash filter, no special action needs to be taken. Due to the moisture content of the barley, you should ensure that the dry matter loaded is the same as when using malt.

Using a lauter tun requires some additional adjustments. When lautering the coarser barley grist, the normal standard lauter programme can be used, for example, when it comes to circulation time and lauter speed. But when carrying out your first trials with Ondea brewing, the raking machine should be set to “hand”, as this setting does not destroy the cake as it should only work on the surface of the cake. After the first wort collection, initiate one deep cut, making sure that at its end, the raking machine is back into first position and once more set to “hand.” For routine Ondea brewing, a separate specific automation programme needs to be developed.

Optimization of the lautering performance can ensure the desired washable extract. Our experience shows, on average, spent grains with extractable extract of 0.5% and washable extract of 1.2%.

Challenge: When using lauter tuns, some problems have been observed when the grist composition was not optimized, resulting in, for example, a run off that was too fast or too slow, a set mash, too many rakings or a decrease in yield. Pilot trials have indicated that 5-15% malt inclusion can improve the lauter performance. So, the addition of a small amount of malt might be an option within the initial phases of Ondea brewing to achieve a robust system when using a lauter tun with grist which is not of optimal composition.

Wort Treatment

When it comes to treating the resulting wort in terms of pH level, salt addition, and hopping regimes, you can maintain your current wort parameters.

Wort Quality and Fermentability

The combination of the mashing profile shown in Figure 4 and 2 kg of Ondea Pro per ton of barley is designed to produce wort of standard quality for the production of a pilsner-type beer.

The barley wort is fully fermentable and demonstrates the same fermentation profile when compared to an all malt wort (Figure 5).

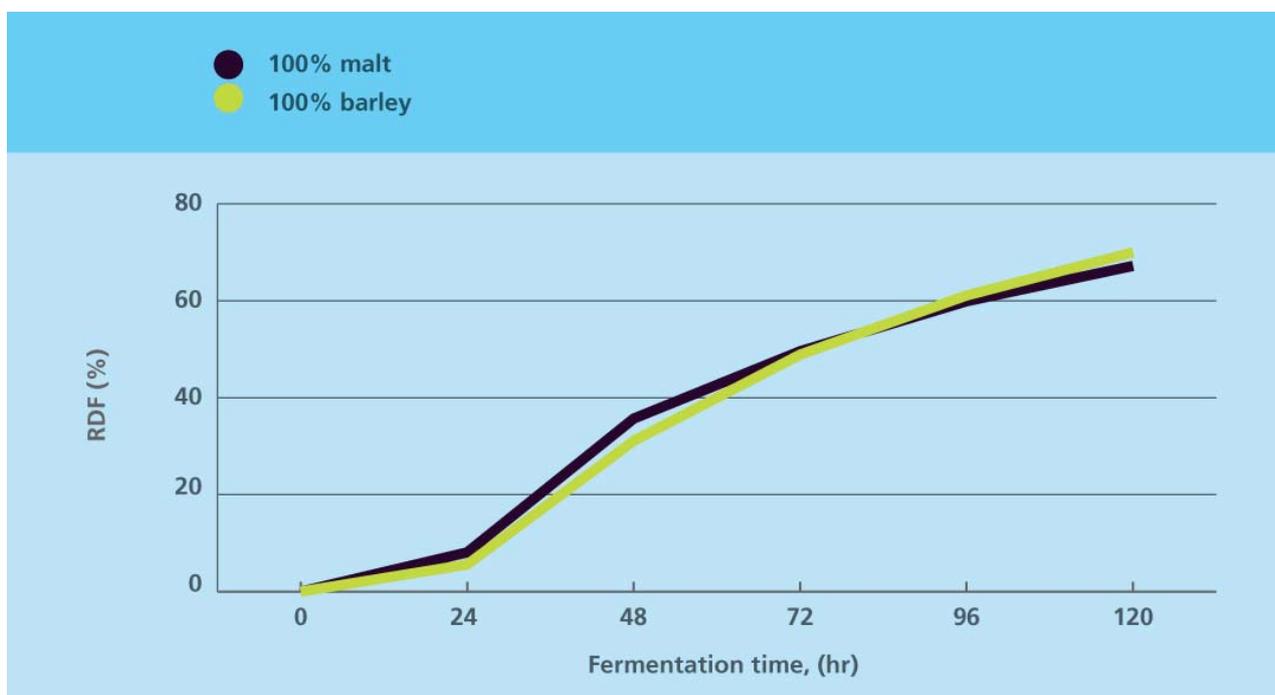


Figure 5: Similar fermentation profile for 100% barley wort and 100% malt wort.

The overall FAN value is lower in the barley wort, but with a much higher percentage of digestible amino acids it needs only 9-10 mg FAN/Litre/%Plato (Figure 2) to ensure good fermentation.

The recommended mashing profile with 2 kg of Ondea Pro per ton of barley will result in a wort with an RDF of approximately 70% (Figure 1) and a sugar profile with high maltose values and a low glucose value (Figure 6).

Both the sugar profile and the fermentability can be adjusted to meet specific requirements by changing the Ondea Pro dosage and/ or the mashing profile.

Sugar profile	
DP1 (glucose, fructose)	5–10%
DP2 (maltose)	45–60%
DP3 (maltotriose)	< 15%
DP4+ (dextrins)	< 22%

Figure 6: Typical sugar profile for a 100% barley wort processed with Onda Pro.

Challenge: In some cases, typically when using Onda brewing in combination with adjunct brewing or special yeast strains, extended maturation time has been needed in order to achieve the required low diacetyl level. Extra FAN may overcome this problem and can be created by extending the mashing-in at 50°C for up to 60 minutes, by selecting the right type of barley with a higher protein content, or by adding a low quantity of malt (10-20%).

Filtration and Stabilization

Good results have been observed with 40 g silica and 15 g PVPP per hl.

Challenge: The stabilization process when using 100% barley as raw material may need further optimization, and Novozymes is continuing to investigate this.

Beer Quality

Great tasting 100% barley beer brewed with Onda Pro has been successfully produced in industrial scale to match global expectations, be it east, west, north or south.

Onda pilsner demonstrates similar composition to a malt based pilsner with respect to Plato, alcohol, haze, pH, gravity, CO₂, foam, RDF, etc. – and, most importantly, similar taste, as illustrated in Figure 7.

	Taste panel according to DLG*				Taste panel with focus on aging			
	100% barley		100% malt		100% barley		100% malt	
	Fresh	Forced aged	Fresh	Forced aged	Fresh	Forced aged	Fresh	Forced aged
Aroma	4.3	3.8	4.2	3.6	1.0	1.4	1.0	1.8
Taste	3.9	3.7	4.0	3.8	1.0	1.6	1.0	1.8
Body	4.4	4.3	4.3	4.3	1.0	1.6	1.0	1.7
Carbonation	4.5	4.5	4.5	4.6	1.0	1.5	1.0	1.7
Bitterness	4.6	4.0	4.0	3.9	100	77	100	70
DLG score	4.3	4.0	4.1	3.9				

Figure 7: Similar taste evaluation scores achieved for 100% barley beer and 100% malt beer.

Challenge: The first 100% barley beers were very light in taste in order to show that the Ondea brewing concept did not give rise to any off-flavours normally associated with traditional brewing with high barley inclusion. Any beer type can be made using Ondea brewing by simply exchanging the barley pilsner-type malt with raw barley and Ondea Pro. At BRAU 2010 we presented three different beer types at the Novozymes stand, a Nordic type pilsner, a German type beer and a stout (Figure 8).

Different beer types with Ondea® Pro

	Barley stout	Barley Märzen	Barley pilsner
Original gravity	14.0	12.4	10.17
Alcohol volume	5.3%	5.6%	4.5%
ADF	71.5%	84.3%	81.8%
Bitter units	25 IBU	20 IBU	19 IBU
Barley origin	Danish <i>organically grown</i>	German	Iceland
Barley variety	Maja <i>old Danish 2-row spring barley</i>	2-row spring barley	Kria <i>very dormant Icelandic variety</i>
Additional raw materials	10% special malt 1% roasted barley	-	-

Figure 8: No limitations to beer types that can be produced based on raw barley and Ondea Pro as an alternative to barley malt.

The next step is to brew any type of beer to target varying local taste preferences based on Ondea brewing.

The Future of Ondea Brewing

The success of the Ondea brewing concept is tightly linked to the question: "Can you make good beer without malt?" Our experience, based on a busy year and more than 100 trials with Ondea Pro, gives rise to a clear and distinct YES in answer to this question. The quality of the 100% barley beer based on Ondea brewing has impressed the brewers. "Surprisingly good" – "tastes like normal beer" – "no off-flavours" have been some of the most frequent comments we have heard. This confident "YES" is a true breakthrough when it comes to the idea of using raw barley instead of malted barley as a basis for beer production.

Of course, basing beer completely on barley is not a new one. At the European Brewery Convention Congress in Estoril in 1971, Nielsen presented trials showing that beer can be made from 100% barley and commercial enzymes (Nielsen, 1971). Malt-free barley brewing has been successfully carried out in Africa for several years, e.g. at Kenyan breweries (Cege, 1999). In 2001, Bamforth presented his "new brewing paradigm," making beer from barley endosperm and commercial enzymes (Bamforth, 2001).

Ondea brewing more than fulfills the visions of Nielsen, Cege and Bamforth, although it does not go quite 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 wort performing in a very similar manner to malt-based wort.

This synergy and the fact that the barley wort is similar to and behaves like malt wort, in combination with the simplicity of the Ondea brewing, could be the reason the resulting beer is of such high quality, in turn, leading to the potential success of the concept. Additional benefits

offered by Onda brewing are raw material savings, opportunities to use local grown barley and reduced CO₂ emissions. The high quality of the 100% barley beer also make it a good candidate for blending with other high quality products, and as base for non-beer drinks and syrups.

The future of brewing seems set to feature Onda brewing as a feasible and flexible option when making beer and other traditionally malt based products. Current trends are increasingly turning to the mixing of barley and malt prior to mashing-in, indicating that the blending of 100% barley beers and 100% malt beers will quickly become an attractive alternative. (Aastrup, 2010).

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