a new alternative

Tritordeum

to wheats and barley

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Published: 05-08-22

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1. Introduction

Tritordeum is an innovative cereal, a cross between durum wheat and barley. It was first produced as a potential new crop some 40 years ago by a group of scientists of a public research institute in Spain. It is a natural cross, and not a GMO. Like wheat, tritordeum can be applied in a wide range of cereal-based food products, in form of flour, semolina, malt and grain (**Figure 1**). Therefore, the end products can be bread, pastries, pasta, beer, flakes, pizza dough, biscuits and many more. The important characteristics of tritordeum are its composition and functionality, its sustainable cultivation, and the traceability of the whole value chain through repurchase agreements with the farmers. Tritordeum is currently cultivated in Spain, Italy, Greece and Australia, 90% in conventional and 10% in organic. It is commercially available in 10 countries in Europe, and is likely to be a recognized part of Europe´s agriculture in near future. The following article introduces the properties of tritordeum and explains why it is a healthy alternative to wheat and barley. Furthermore, its functional characteristics and how to work with tritordeum in bread making will be explained.

Figure 1: Tritordeum ingredients: grain, malt, flour

2. History and Breeding

The development of tritordeum started in the early 1980s, with a group of scientists who were interested in combining the positive characteristics of barley and wheat. Searching for barley species with interesting characteristics which could be crossed with wheat, they conducted five expeditions to south America. The group collected a wide range of examples of the Chilean wild barley (*Hordeum chilense*) which can grow from coastal regions right up to mountain areas. They used the *H. chilense* lines to cross with durum wheat (*Triticum durum*) collected from international germplasm collections. Through inter-specific hybridization (crossing by hand in field) between the two species, the scientists created a completely new cereal species that is suitable for human nutrition. Tritordeum is not a GMO, having been made by standard breeding techniques, and it possesses a series of positive agronomic, technological, nutritional and sensory properties. The initial goal of the researchers was to find a cereal that can be grown in dry regions of the Mediterranean, where cereal harvests are often limited because of abiotic stresses. However, in addition it was found that due to the influence of its barley genes, tritordeum has a higher resistance to diseases such as rusts, Septoria and mildew.

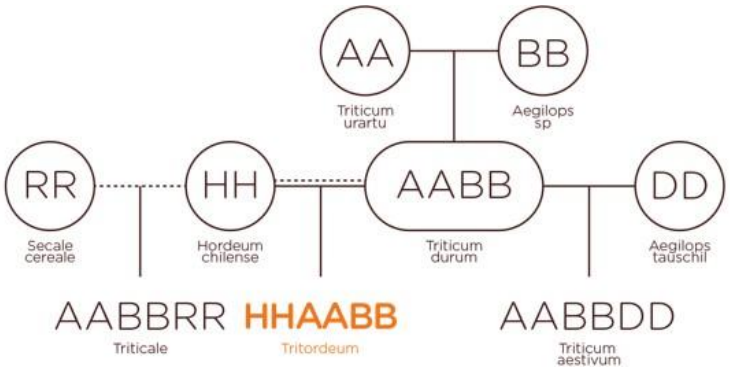

Figure 2: The Origin of tritordeum is the cross between Hordeum chilense and Triticum durum.

Tritordeum is a hexaploid species, like bread wheat or triticale and contains two genomes of wheat (AABB) and one genome of barley (HH) (**Figure 2**). In the early years of crossing and selection, the Spanish scientists concentrated on agronomic performance, to develop tritordeum lines which could compete with conventional cereals. After several years of development, the focus shifted towards the selection of lines with good properties for baking and more recently malting. In the beginning, the researchers worked with a collection of some 250 primary tritordeum produced from crosses between many combinations of *H. chilense* and durum wheat parents, which became the basis for the breeding program. Today there is a large collection of advanced lines with different agronomic and functional characteristics. Two commercial tritordeum varieties (Aucan, 2013 and Bulel, 2015) have been registered with the EU Community Plant Variety Office (CPVO) and 10 new advanced lines are under final evaluation in preparation for registration. The breeding program (**Figure 3**) is still based in southern Spain, but with aim of expanding the area of cultivation, advanced lines are grown in trials in other countries to evaluate their performance in comparison with local cereals.

Figure 3: Breeding program in Cordoba, Spain (2022).

As a crop, tritordeum resembles wheat more than barley, concerning its morphology, growth habit, crop management and grain characters (**Figure 4**). The current commercial varieties are best adapted for cultivation in Mediterranean areas. Tritordeum is grown as winter cereal and is well suited for organic production, as it has moderate needs for fertilization and reduced

requirement for fungicides because of its good resistance to common cereal pathogens. The main cultivation regions today are in Spain, Italy, Greece, and Australia. In addition, multi-local field trials are performed in geographies like France, The Netherlands, Poland, United Kingdom.

Figure 4: Tritordeum plant and field. (Variety: Bulel)

3. Grain composition and properties

In several areas of grain composition tritordeum shows valuable nutritional and health benefits. In comparison with bread wheat, there are significant differences in the composition of gluten and in the content of lutein. In addition, tritordeum has a higher content of fiber, fatty acids, and starch-degrading enzymes. These differences mean that tritordeum flours have different functional and organoleptic qualities from conventional cereals.

3.1 Gluten

Gluten is essential for the bread making process. The gluten proteins (with glutenins and gliadins forming the two major groups) can produce tiny filaments which trap the carbon dioxide gas produced by yeast during the fermentation. The general level of gluten proteins in tritordeum is like that in bread wheats, but the composition of gliadins shows differences from bread wheat.

A study by Vaquero et al. [2] analyzed the gliadin composition of tritordeum in comparison with wheat and examined the acceptance and digestibility of tritordeum breads, wheat breads and gluten-free breads. Flour and bread samples were analyzed to identify differences between commercial bread wheat flour and tritordeum flour and the changes occurring in the different fractions of gliadin during the processes of breadmaking, fermentation and baking. The comparison (**Figure 5A**) shows the differences in the gliadin composition between wheat and tritordeum flour samples. In particular, the α- and γ-gliadin fractions showed qualitative differences in composition between wheat and tritordeum, although the total content of those gliadins was not significantly different. Regarding ω-gliadins fractions, tritordeum flour showed a significantly reduction compared with wheat. The total gliadin content was slightly lower in tritordeum.

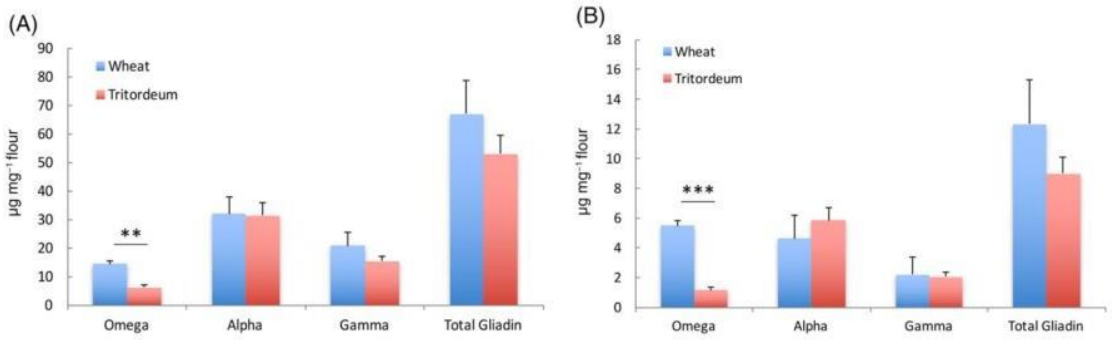

Figure 5: Gliadin distribution in flour (A) and bread (B) from wheat and tritordeum samples expressed as µg protein
mg-1 flour.

After fermentation and baking, the gliadin composition in both cereals showed a clear decrease in the content of α- and γ-gliadins compared with the levels in flours (**Figure 5B**), but the ω-gliadin fraction was more strongly affected with a reduction of around 55% in wheat bread and a reduction of 80% in tritordeum bread.

The content of gluten in flours and breads, as measured by competitive ELISA R5 analysis, was significantly lower in tritordeum than in wheat, with a reduction of 41% in flour and 49% in bread. The study by Vaquero et al., included a nutritional trial in which healthy volunteers consumed wheat bread, tritordeum bread or gluten free bread over a one-week period and the excretion of immunogenic gluten peptides (peptides associated with celiac disease and non-celiac gluten sensitivity) was measured. It was seen that the excretion of immunogenic peptides was lower with the tritordeum diet than with the wheat diet. The acceptability of tritordeum breads was good, like wheat, and significantly better than gluten-free breads. The results of the study suggest tritordeum could be an alternative for people who want to reduce their intake of gluten, but that it is not suitable for coeliac disease sufferers.

3.2 Lutein

Lutein is the major carotenoid contained in all cereals. It is the pigment which gives color to cereal products. Tritordeum in comparison with other cereals has high lutein content, up to ten times more than bread wheat, which gives a clear golden-yellow color in tritordeum products. High carotenoid content is strongly required for high-quality pasta making. It gives the pasta an appealing yellow color, which consumers often value in bread and other products as well (**Figure 6**). Another significant finding is the high esterification degree of lutein found in tritordeum compared to durum wheats, which is an important characteristic for bioavailability of the compound [3]. Next to the strong influence on the color of the product, lutein is beneficial for eye health, specifically it helps prevent age- related macular degeneration. Furthermore, it decreases the risk of developing certain cancer types, and it supports the skin protection against UV rays. The high lutein content in tritordeum does not influence the processing properties and handling and it may contribute to its characteristic organoleptic (aroma and taste) properties. Tritordeum contains 10 to 15 times more lutein than other gluten-containing cereals (**Figure 7**).

Figure 6: Comparison of breads made with 100% tritordeum flour (left), 25% tritordeum flour (center) and 100% wheat flour (right). Fresh pasta made with 100% tritordeum flour.

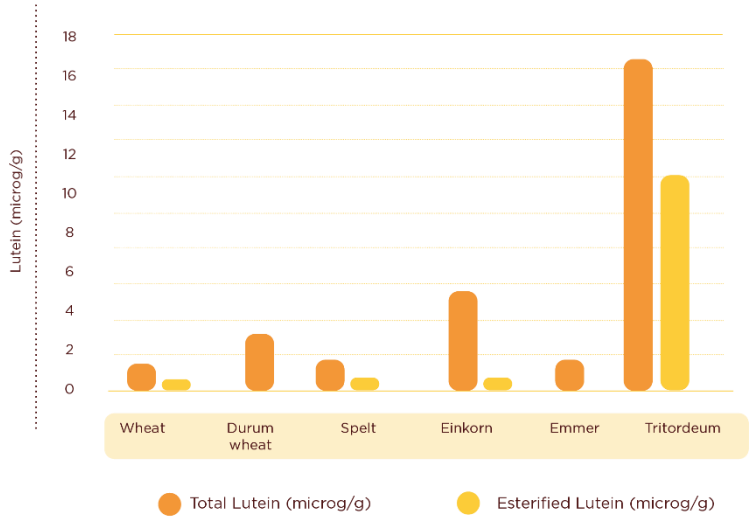

Figure 7: Comparison of lutein and esterified lutein contents in gluten-containing cereals.

3.3 Fiber

Tritordeum flour has higher dietary fiber content than wheat, which has a positive effect on the cardiovascular health of humans. It contains around 30% more total dietary fiber. Next to the impact on cardiovascular health, the high fiber content facilitates intestinal transit, and expands in the gut to increase the feeling of satiety. Furthermore, tritordeum contains a high content of fructans that are active prebiotic compounds that stimulate the development and the balance for our gut flora [4,5] (**Figure 8**).

Cereal	Fructanes (g/100g)
Rye	3,86
Durum wheat	1,84
Aestivum whole	1,82
Tritordeum whole	1,75
Barley	1,59
Tritordeum white	1,49
Aestivum white	1,32
Spelt whole	1,32
Spelt white	1,13

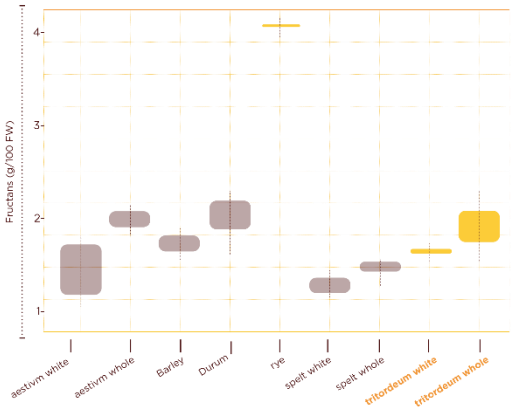

Figure 8: Comparison of fructan content in gluten-containing flours

3.4 Oleic acid

Apart from the positive impact of the fiber and the lutein, tritordeum has higher levels of fatty acids than bread wheat, around 80% in stoneground flour and 60% in refined flour. The content in oleic acid content is elevated, at 48% higher than wheat in stoneground flour and 29% higher in refined flour. Oleic acid is considered the most important fatty acid of the Mediterranean diet. It is also well known for its benefits on cardiovascular health, which builds together with the fiber content a positive combination [6].

3.5 Enzymatic activity

Tritordeum has a very good enzymatic activity (especially alfa and beta-amylase activities), which makes it very suitable to be malted to obtain HDP malt (High Diastatic Power malt). This characteristic is very well appreciated in brewing but also distillery and baking applications. In comparison to barley and wheat, Tritordeum has the potential to outperform both species in such applications (**Figure 9**)

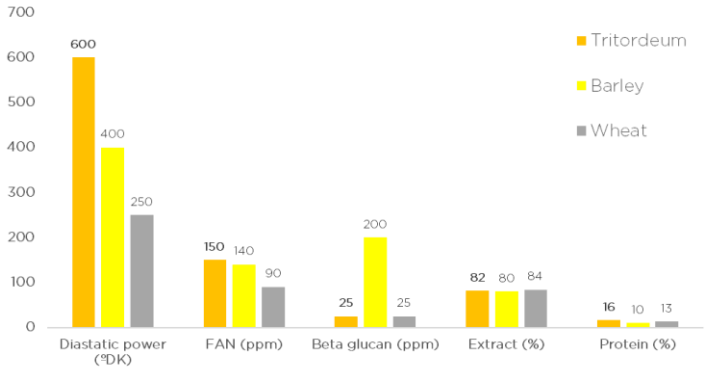

Figure 9: Malt analysis of tritordeum, barley and wheat

4. Bread making quality

Tritordeum inherits the proteins from both genomes, barley and wheat, which are responsible for its quality characteristics. If hexaploid tritordeum is compared with wheat and triticale (the other main hexaploid cereal types), tritordeum has similar quality traits to those of bread wheat. The viscoelasticity of tritordeum dough for processing quality means that it is more suitable for bread making than for pasta making.

[7] Although tritordeum is a combination of durum wheat and wild barley, its behavior in the baking process is nowhere near to its parent cereals. Tritordeum behaves similarly to medium-strength bread wheat (W120-150). It can substitute partially wheat in wheat-based recipes to improve the dough behavior (better extensibility), the color (natural yellow coloring), and the overall sensorial profile (short-bite crumb and pleasant, sweet smell and taste) and it can be baked at 100%, when one knows how to handle its special properties.

To understand how to bake tritordeum properly, it is important to first look at the nutritional profile of the flour. When looking at a cylinder-milled refined flour with 70% extraction rate, we can observe a good level of protein (usually above 13%), a high level of dietary fibers (above 6%), especially arabinoxylans, which will confer a very good water absorption, a high level of fatty acids (above 2,5%), especially oleic acid, which will give a cake- like feel to the crumb, and a very good enzymatic activity, especially amylase activity, which helps to shorten overall proofing time, and reduce glycemic index of baked goods (**Figure 10**)

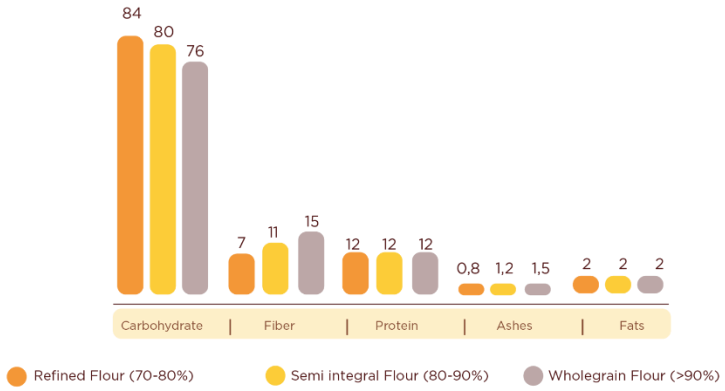

Figure 10: Flour analysis of tritordeum

When used at 100% in a bread recipe, Tritordeum can be baked without extra additives with a craft-type process, but it does require additives in mechanized baking processes, similar to wheat flours.

4.1 Tritordeum in "craft" recipes

Tritordeum flour has a very good water uptake capacity, and therefore it is recommended to work with water ratio of 70% minimum. Depending on the final water content of the recipe and the desired crumb structure, an autolysis (resting of flour and water) is highly recommended for levels of water above 75%, to ensure proper hydration of starch, and shorten the kneading time. Although tritordeum contains a good level of gluten, its gluten is weaker than that found in common wheat, and therefore its tolerance to kneading is lower. Other recipe options are possible, like the use of natural sourdough (fermented flour culture)

in the recipe up to 30% on a flour basis, which contributes to better absorption of water in dough, or the use of a poolish base (mixture of flour, water and yeast), at up to 40% on a flour basis, with the same effect.

The kneading step is very important when working with 100% tritordeum flour in the recipe. It has to be short, and with low intensity (usually in first gear). The final dough temperature has to be below 24ºC to have time tolerance in the posterior proofing step, especially with lower-weight pieces (below 350gr). For baguettes it is recommended to have a dough temperature of 22ºC, and for loaves, 24ºC is acceptable. The dough has to present a homogenous consistency, with a smooth/shiny surface, and good gluten network development - usually tested by extending a small dough piece, trying to form a film.

A bulk rest of the dough is highly recommended to further strengthen the dough, reduce stickiness, develop a better opened-crumb structure and, in cold long bulk-rest processes, develop a more intense flavor and taste. Stretching and folding of the dough during the bulk rest will be beneficial for loaf formats, but not for baguettes.

The second proofing time must be very short in comparison with a similar wheat-based format. The ideal proofing conditions are below 25ºC, as otherwise the strong natural enzymatic activity of tritordeum will degrade the gluten network very rapidly. For a baguette format, the resting time in shaped pieces has to be less than 15min, and for loaves up to 45min. The dough will gain a maximum of 50% volume between the end of mixing and the moment it goes in the oven.

Tritordeum dough after kneading

Tritordeum bread after baking

Tritordeum dough at proofing

Tritordeum crumb structure

Figure 11: Tritordeum at each step of the bread making process

Baking of tritordeum is similar to any other baked product and depends on format and unit weight. For baguettes, enter the dough at 250ºC, and reduce to 230ºC after 10min. Baking time is usually below 30min. For Loaves, enter at 230ºC with a baking time around 40min for 500gr dough pieces. (**Figure 11**)

4.2 Tritordeum in "industrial" recipes

As a new species of cereal, tritordeum has its own unique nutritional composition, and to optimize its performance in industrial baking processes, it requires a specific set of correctors to solve the typical dough handling problems encountered.

The recommendation is to combine an antioxidant agent such as ascorbic acid at a dosage of 5-10gr/100Kg, with a "cocktail" of enzymes acting to modify the 4 main groups of nutrients: starch, protein, fiber and lipid.

A gluco-amylase will provide dryer dough and soft, yet chewy crumb structure. A xylanase will provide second proofing stability and better dough strength.

A phospho-lipase will act as an emulsifier giving more tolerance to dough during kneading and improve final bread volume.

A glucose-oxidase may improve further the dough handling in case of higher water content in the recipe.

The adaptation of the baking process at industrial scale should follow the same indications as in a craft process: a shorter/less intense kneading stage, a bulk rest, when possible, a shorter second proofing time. Whether the production line is extrusion or lamination, tritordeum can be handled when the proper recipe and flour correctors are used. (**Figure 12**)

Figure 12: Tritordeum flour processed on a laminated line, and baked bread

4.3 Tritordeum in other bakery applications

Tritordeum flour is very suitable for pastry and biscuit applications thanks to its natural golden color, similar to the color given by egg/butter, and its naturally sweet taste and flavor, which is also a key attribute of sweet bakery products.

In chemically leavened applications such as biscuits, sponge cake, pound cake, muffins, madeleines (**Figure 13**) the replacement of wheat flour with tritordeum flours allows the baker to increase the ratio of liquids (water, milk, egg, oil, etc) and if desired, to reduce other raw materials like sugar, egg, butter, without losing the golden color and sweetness of the baked good. In trials, reductions of 5 to 10% of these ingredients has given good results.

Figure 13: Tritordeum biscuit

In yeast leavened applications such as brioche, croissant, Danish pastry, etc, tritordeum will provide extra color, flavor and taste (**Figure 14**); but it has some limitations in its use due to the fact that its gluten network is not as strong as that of the wheat flours usually recommended for such products. A combination of tritordeum (up to 70%) and wheat is therefore an option to avoid an unacceptable loss of dough stability and baked good volume.

In specialty applications such as savory crackers, grissini… the use of 100% of tritordeum flour is very suitable without process difficulties.

Figure 14: Tritordeum brioche

4.4 Other Tritordeum flours

In addition to refined flour, tritordeum is also available in semi-whole meal (80% extraction rate) or whole meal flours (95% extraction rate), in both cylinder as well as stone milled. These flours contain higher levels of ash and fiber and provide richer and fuller taste profile. The baked product color obtained with those flours is darker than with refined flour, with a brownish crumb color (**Figure 15**).

Figure 15: semi-whole meal and whole meal Tritordeum breads

Those flours have to be worked with in similar way as refined tritordeum flours but making allowance for the higher fiber content.

5. Conclusions

Tritordeum is a new cereal combining the best attributes of wheat and barley, converting it in a suitable alternative to those cereals in their respective applications: baking, pasta, malt,… Its nutritional composition stands out on the gluten composition and tolerability, the higher fiber (fructans) and oleic acid contents, as well as excellent enzymatic activity resulting in the recent interest from the brewing and distilling industries.

In baking applications, the craft sector has been the first-mover on that new cereal, and more than 1000 craft bakeries in Europe are offering bakery products made of tritordeum on a daily-basis. The consumer acceptance has been very positive thanks to its nutritional characteristics, but also superior sensory profile.

Vivagran (www.vivagran.nl), the company in charge of the commercialization of tritordeum on a global scale is active in supporting all actors of the local value-chains established by country, and also actively looking for new commercial partners to expand its reach with its proprietary new grain.

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7. Analysis conducted by Vivagran