Einkorn Explained

The Healthy Alternative to Hybridized Wheat

Dr. Susana Domínguez Rovira & Albert Bruno Llach

Contents

Einkorn field, El Bosque, Spain

Welcome to the Revival!

Based in Southern California by way of Barcelona, Spain, Revival Einkorn is the culmination of a decades long, single-minded pursuit to bring nutritious, whole and regenerative foods to market.

A unique collaborative effort driven by an international crew of Bakers, farmers, nutitionists and organic food entrepreneurs, Revival Einkorn seeks to change the way we eat by reviving the ancient food wisdom the modern world left behind.

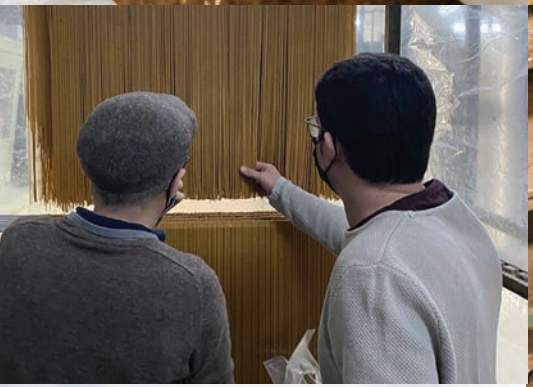
Twenty years is just a blip when compared to the history of einkorn, which dates back more than 14,000 years, but in the world of natural and organic foods, it's a lifetime. And, a lifetime is exactly what Revival Einkorn founder, Werner Forster, has devoted to his hunt for a truly revolutionary grain.

He didn't start out looking for a better wheat. Early on he observed firsthand the alarming trends tied to our increasing dependence on processed foods and decided to do something about it. With years spent disrupting commercial food industries—revolutionizing decades of harmful growing practices within the organic fruit trade and pioneering practices to make aquaculture truly healthful, regenerative, and sustainable—Forster and his wife, Maria, are now disrupting the business of deficient wheat with Revival Einkorn's painstakingly perfected einkorn products.

After so many years of dedicated work, Werner, Maria, and the entire Revival Einkorn team are thrilled to share these delicious, nutritious einkorn products with you.

Revival Einkorn founders Maria & Werner Forster, Jerez, Spain






Over an eight year project, 'Einkorn Explained: A Healthy Alternative to Modern Wheat' was developed and re-developed to highlight einkorn's unique composition (as a food source), place in history, and to help support the launch of a new einkorn brand; Revival Einkorn.

Dr. Susana Domínguez Rovira, M.D.

Doctor Susana Domínguez Rovira specializes in pediatrics, children and family nutrition at Hospital Sant Joan de Déu in Barcelona which is the foundation of her work. She has a Masters Degree in Nutrition from Universidad Europea del Atlántico and provides nutritional coaching. In addition, she has diplomas in the study of 'Vegetarian Diet' and 'Celiac Disease' respectively - which in fact introduced her to einkorn. She was particularly drawn to einkorn's extremely low gluten and inflammatory properties relative to celiac disease and other digestive issues. But she was convinced it was really something special when she learned about its dense vitamin, mineral, antioxidant and protein content – and the numerous other attributes this humble wheat had to offer. Dr. Rovira also has a deep interest in getting back in touch with the heritage or original foods mother nature provided – and how those heirloom crops might help her patients on a healthier (and more natural) nutritional path.

Albert Bruno Llach, Revival Einkorn Food Scientist & Nutritionist

Albert is an amazing baker... who also just so happens to be a *Dietician Nutritionist Naturopath* with a special interest in inflammatory diseases and the role that wheat can play in them. It all began in an organic bakery in Barcelona where he worked for over ten years. The ancient and heritage wheats that they worked with, really caught his attention. That interest continued through his nutrition studies at university where he delved (deeply) into the comparison between modern and ancient wheats with a special attention to *monococcum*. With more than 15 years experience in organic ancient wheat baking as well as his own nutritional consultation practice, Albert says he's still learning everyday from the people that teach him the most. The farmers, the researchers and his patients. And from his favorite wheat, *T. monococcum*, einkorn.

Einkorn is the first (and arguably best) wheat. With gluten intolerance and "diseases of plenty" on the rise, it's time to rediscover this ancient grain.

Einkorn being de-hulled

Introduction

Einkorn, Jerez, Spain

...not all wheat was created equal.

Wheat is one of the most historically significant plants in human history. Hunter-gatherers initially gathered einkorn berries, and during the early Neolithic period, they transitioned to farming einkorn. Wheat has played a primordial role in the human narrative for over 14,000 years, catalyzing the development of agricultura as we understand it today and sustaining the epoch of the human innovation and exploration.

But not all wheat was created equal. Evidence suggests that the first domesticated wheat was *Triticum monococcum spp monococcum*, (hereafter "einkorn"), a direct descendant of the wild variety *T. monococcum boeticum*. Hardy, drought tolerant and naturally resistant to pests, einkorn is high in protein and essential nutrients, far more so than modern varieties of wheat. Then there's the issue of digestibility. Given that gluten intolerance is at epidemic levels—with some surveys suggesting that as many as 30% of Americans currently avoid wheat—this is of no small importance. That's why it's so significant that einkorn's gluten is substantially simpler and easier to digest compared with that found in modern wheat varieties.

As will become clear, in dietetic terms einkorn is superior to modern wheat varieties in every regard. If hybridization and genetic engineering have greatly increased the yields of modern wheats, this material bounty has enacted an unsustainably high cost, both for our health and the health of the planet. Compared with einkorn, modern wheats typically require vast inputs of chemical fertilizers and pesticides, impoverishing the soil in which they're grown and significantly contributing to human-caused climate change.

Given the prevalence of "diseases of plenty" such as obesity, diabetes, depression and various cancers, the arguments for rediscovering einkorn aren't merely academic. A grain with the potential to reframe our current unhealthy relationship with modern wheat, einkorn is an ancient wheat whose second act is only beginning.

1. Einkorn's Historical Background

Einkorn once shaped the human story, but the rush to greater yields nearly wiped out the very first wheat.

Though einkorn was the first domesticated wheat, by the modern age it had all but disappeared from the human diet. The reasons have less to do with its appealing flavor, high nutritional content, and tolerance to challenging growing environments, and more to do with a desire for higher yields. But as noted above, the results have been questionable for human health. One reason is that while we've had many thousands of years in which to adapt to the consumption of einkorn, we've had only centuries—or, in some cases, mere decades—for our systems to become accustomed to modern wheat flours. To understand this, it's helpful to recap the story of einkorn .

Einkorn was first cultivated approximately 14,000 years ago in ancient Mesopotamia. Thousands of years later came emmer and spelt, which belong to the group of "dressed" wheats whose husk is firmly attached to the grain and must be removed to process the flour after threshing. Thanks to this shell and its unique spike, einkorn is highly resistant to diseases and the aggression of parasites. This shell also helps the berry to retain water, though it's the plant's deep root system which most contributes to the plant's ability to tolerate arid conditions and poor soils. Because of this, einkorn is able to be cultivated in marginal soils where other species are not viable.

The Neolithic Revolution was without doubt one of the most profound reorderings of human society. The grain that powered it? Einkorn.

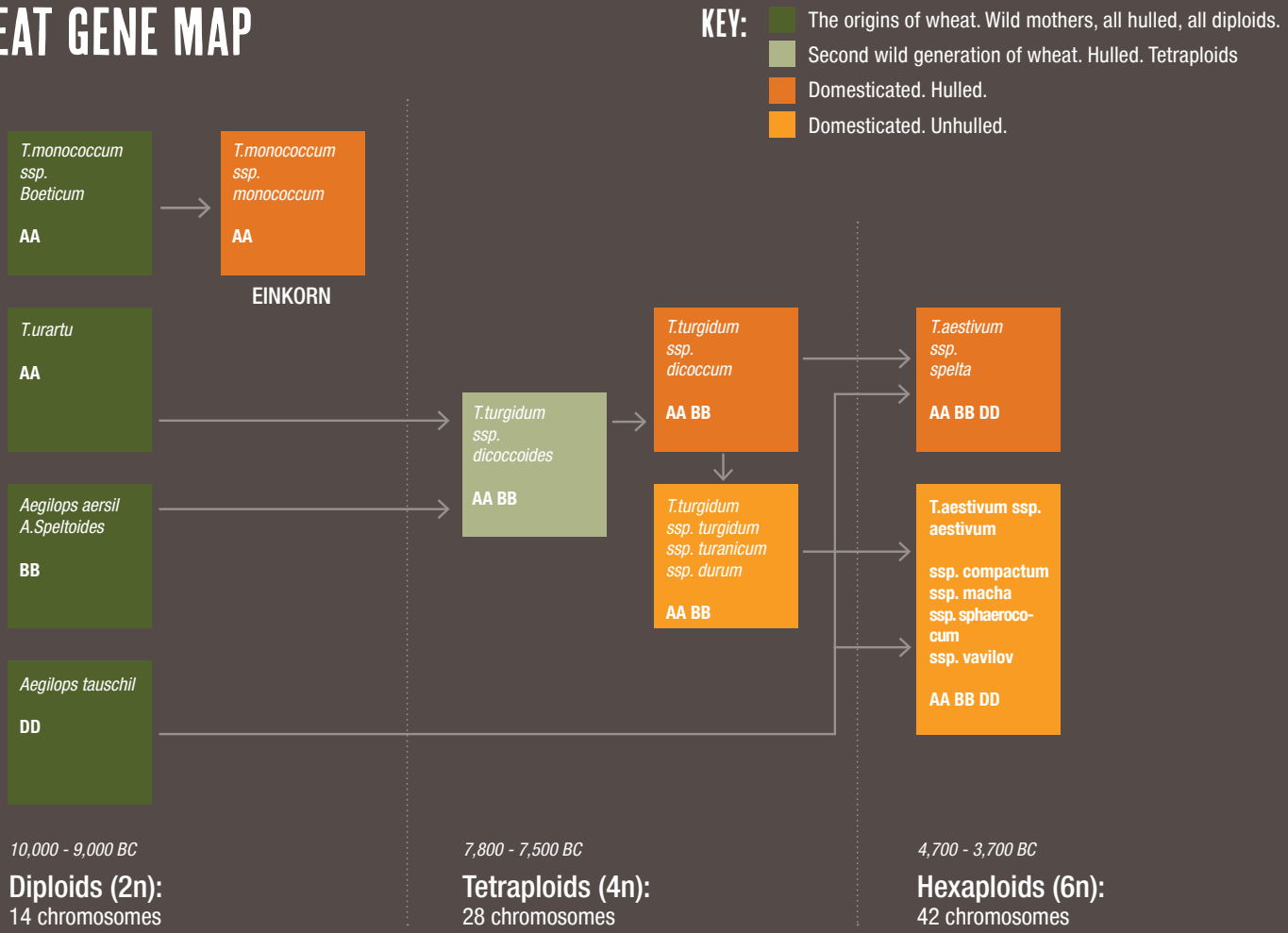
During the Neolithic Revolution, einkorn spread from the Caucasus throughout Europe. It is called "enkir" in much of Western Europe, "little spelt" in England, "petit épeautre" in France, "piccolo farro" in Italy, "espelta pequeña" or "escaña" in Spain, and "einkorn" in Germany. Cultivars of einkorn still survive in various regions, including Northern Anatolia, the Balkan countries, Spain, Germany, Italy, France, Switzerland, and Morocco.

The current non-mechanized cultivation of the "checkalia" variety of einkorn has been documented in the western area of the Rif, in the North of Morocco (Peña-Chocarro et al , 2009). This ethnographic enclave serves as an excellent environment in which to study techniques that have been developed for its cultivation, harvest, and processing, providing a living example of the possibilities of regenerative agriculture. Einkorn's wild parent , T. monococcum spp boeoticum , still grows in the eastern and central Fertile Crescent (a historical region encompassing part of the eastern Mediterranean, Mesopotamia, and part of Persia), where the grain is used to feed humans and cattle and—anecdotally at least—the straw is still used to construct roofs. The domesticated form is similar to the wild one, with the difference that its spike remains intact when it matures and its grains are somewhat larger.

Archaeological studies confirm that this wild wheat was consumed long before the advent of agriculture, well into the Paleolithic period. (Arranz Otaegui A. et al , 2018). Once domesticated, this form was for millennia one of the most important staple foods for European farmers. Analysis of the contents of the intestinal tract of "Ötzi"—the Copper Age shepherd whose remains were found in the Italian Alps in 1991—reveal that his last meal included einkorn. Ötzi died around 3255 BC and is the oldest fully preserved human being. After his dwelling was attacked and he was wounded, he fled to a nearby mountain and died there. Inside his pockets and stomach were found the remains of einkorn grains (Zaharieva et al , 2014). With the advent of the Bronze Age (3000 BC), cultivation of einkorn declined until it was practically abandoned, replaced by cultivation of tetraploid (T. turgidum) and hexaploid wheats (T. aestivum). These "inherited" wheats are the hybridized descendants resulting from crosses of wild and cultivated species.

With a higher endowment of chromosomes, they provide a greater agronomic yield. However, their more complex gluten structures—in addition to having much higher quantities of immunogenic peptides—make them more difficult to digest.

WHEAT GENE MAP



WHEAT IN THE MODERN ERA

Anxious to feed a growing world, wheat was subjected to intensive cross-breeding and hybridization starting in the post-WWII era.

But was it for the best?

Since 1950, the most recent wave of hybridization of wheat has facilitated increased agricultural production, helping to alleviate famines resulting from the World Wars and other conflicts during the first half of the century. Crossing different strains of wheat also permitted the development of technologically advanced flours. But as a result, hibridized wheat has a significantly greater genome number than T. monococcum.

For simpler wheats, flour is simply the end result of the grinding of grain. Today's flours, by comparison, result from the mixture of the different components of wheat––berry, hull, chaff, and germ––separated and then recombined in different proportions according to their final purpose. Today, wheat and its products—bread, pasta, pastry, etc.—provide 30% of carbohydrates, 30% of proteins, and up to 25% of fiber to the world's population (Scherf KA, 2019). In recent years, the trend toward low-impact agriculture, together with a growing interest in food's nutritional aspects, has led to a rediscovery of einkorn. Several research projects indicate that einkorn has enormous potential for human consumption for five primary reasons: Its nutritional value, its very low immunogenic profile, its non-inflammatory and, in light of recent studies, even anti-inflammatory characteristics, and its contribution to intestinal health and a pleasent taste. We'll examine each of those, one at a time.

2. How einkorn fights inflammation

Inflammation is a natural immune response, but it's often triggered by gluten. Here's how einkorn's unique "Gluten AA" reduces (and may even prevent) it.

As noted earlier, wheat has contributed significantly to the human diet since the birth of agriculture. Indeed, it's highly likely to have sparked agriculture as we know it. But today, a growing percentage of the population either experiences negative gastrointestinal effects after consuming wheat, or perceives wheat to be generally unhealthy. And as we'll explore in a moment, a small but statistically significant proportion of us suffer from celiac disease, a serious—and in extreme cases life-threatening—autoimmune disorder triggered by the consumption of wheat. Some people predisposed to experience adverse reactions to wheat find their sensitivity can be triggered by inhalation or even physical contact to wheat, over and above the ingestion of it. Einkorn may present a viable alternative. In an in vitro study, Antognoni and his collaborators compared the effects caused by four different breads made from einkorn and hybridized wheat, each fermented with sourdough or with conventional yeast.

The study, which made use of a laboratory digester simulating the processes of human digestion, found that inflammatory responses were lower with bread made from einkorn. To compare other such "ancient grains" with einkorn, the cytotoxicity of common wheat has been shown to be greater than spelt (Van den Broeck, 2010), which has been shown to be greater than emmer, which has been shown to be greater than einkorn (Dinu, 2018).

Such studies make use of cellular models to allow the rapid and extensive study of the antioxidant and anti-inflammatory effects associated with different wheats. And again, the data extracted from a limited number of immunological toxicity studies indicate that ancient wheats generally express lower levels of immunoreactive T cells than do modern wheats.

This adds weight to a review of animal and laboratory studies of ancient wheats from 2010 through 2019. The review concludes that—despite the fact that the inflammatory mechanisms involved are not entirely clear—the constituent elements of ancient grain species such as einkorn exert some role in the positive modulation of intestinal inflammation or / and permeability (Spisni et al , 2019).

These findings accord with our understanding of how ancient grains function in the context of a balanced diet. Unlike einkorn, modern wheat varieties don't appear to spur improvements in the amount of proinflammatory cytokines such as TNF alpha and IL-6. This supports the conclusion that otherwise healthy individuals with

cardiovascular risk or type 2 diabetes mellitus could benefit from the inclusion of ancient wheats in the framework of a well-planned Mediterranean diet (Dinu et al , 2018). There are even indications that einkorn could exert a proactive effect on inflammation. A study conducted on pigs fed with einkorn bread points to einkorn's having not only an non-inflammatory effect, but even pointing to an anti-inflammatory one (Barone F. et al , 2018).

THE GLUTEN QUESTION

Why modern wheat proteins cause inflammation (and einkorn's don't).

Gluten is a polymer formed mainly by insoluble proteins in wheat, and it's believed to be the primary cause of inflammation in food. But gluten isn't a single substance; it's a family of proteins that give breads elasticity and allow them to rise. So it's important to note that there are as many types of glutens as there are species of wheat. And as noted above, there are profound differences between the gluten found in einkorn compared with those found in other wheats. Glutens contribute structure and form to wheat products. However, they can also trigger inflammation, discomfort, and in a statistically significant proportion of the population, acute dramatic metabolic derangements including severe diarrhea, hypoproteinemia, and metabolic

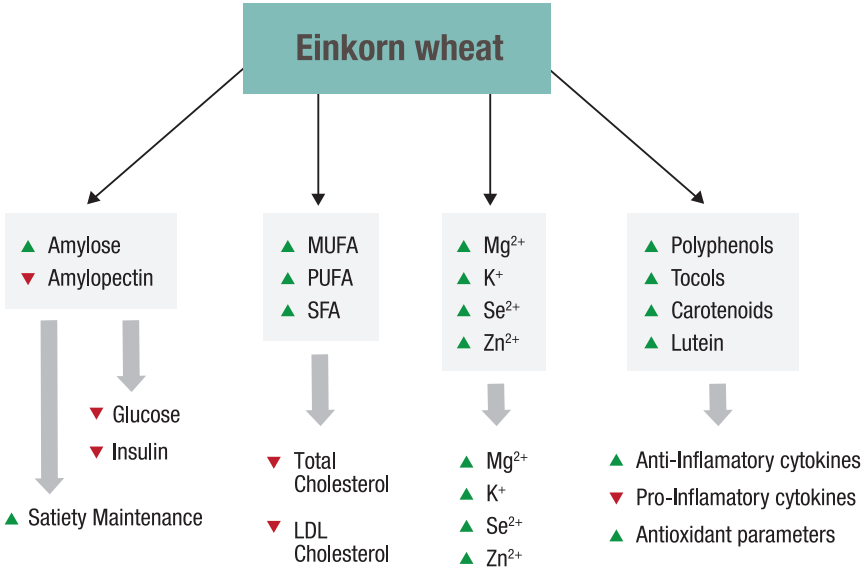


Figure 5: Effects and possible mechanisms of ancient wheats' components on glycemic, lipid, and mineral profiles (Source: Dinu, 2018)

and electrolyte disturbances. In extreme cases, these can be life-threatening. Part of the reason comes down to the relatively complex structure of modern wheat's gluten. Einkorn is—like you and every other human being—a diploid. This means that its genetic structure is composed of two sets of chromosomes, making a total of 14. By comparison, due to extensive hybridization, modern wheat is a hexaploid, having six sets of chromosomes and a total of 42chromosomes.

This hexaploid genetic structure gives modern wheat a higher load of gliadins and glutenins, and these are heavier than those your body evolved to thrive on. By comparison, einkorn contains a significantly lower amount of glutenins, especially in the high molecular weight (HMW) glutenines (Vacciono P et al, 2008). Its prolamine has a lower molecular weight, and the gluten it develops is beneficial to digestion without causing inflammation.

Fresh stone-milled einkorn flour

CELIAC DISEASE AND NON-CELIAC GLUTEN SENSITIVITY

Clues to a painful and potentially life-threatening–gluten-related illness.

Celiac disease (CD) is a multisystemic disease with an autoimmune basis, caused by sensitivity to dietary gluten and other related proteins in genetically predisposed individuals. It is estimated to affect between 0.7% and 1.4% of the population. Then there's non-celiac gluten sensitivity (NCGS). A still-emerging syndrome believed to be associated with the proteins generically known as amylase-trypsin inhibitors (ATIs), NCGS is believed to afflict between 0.6% and 6% of Americans.

We'll dive deeper into the topic of NCGS and ATIs in a moment. But for now, it's important to understand that– while all wheats are recomended not be consumed by those already diagnosed with CD–it's not an inflammation risk compared with hybridized wheats, and presents few if any issues for those diagnosed with NCGS. As it relates to CD, we now know that the greatest content of harmful active epitopes of alpha and gamma gliadins are located in genomes A, B, or D, with the loci of the D genome exhibiting greatest toxicity for T lymphocytes (Van Herpen, 2006). By comparison, einkorn has nor D genome (Scherf KA, 2019). In other words, the genome most responsible for the aggravation of CD doesn't exist in einkorn.

Several peptide sequences—short chains of amino acids found in wheat and countless other living beings—are known to trigger CD. Einkorn contains fewer of these sequences, for example the 33-Mer very highly immunoreactive peptide encoded in the D genome (Vaccino P et al, 2008). As noted elsewhere, the gluten proteins in modern wheat responsible for specific baking attributes—such as chewiness and ability to rise—are rich in the amino acids glutamine and proline, classified together as prolamines. And prolamines—including but not limited to gliadins—are responsible for triggering the inflammatory response that atrophies the villi leading to malabsorption and immune dysfunction in individuals suffering from CD.

The long peptides of these prolamines–whether incomplete fragments and short complete chains–are still small enough to cross the intestinal barrier intact and are "recognized" by the immune system through the small sequences known as epitopes (Schopf & Scherf, 2018). In those afflicted with CD, the immune system initiates a rapid cytotoxic reaction which in turn damages the intestinal epithelium.
An adaptive response is more long-term. It is mediated by T lymphocytes that, having recognized these epitopes, bind to specific molecules expressed on the surface of antigen-presenting cells and cause the T lymphocytes to produce inflammatory cytokines, damaging the intestinal membrane and causing more inflammation and long-term malabsorption of nutrients.

To understand why, it's helpful to know that hybridized wheats aren't direct descendants of einkorn. Rather, they're hybrids that have resulted from crossing different species with a variety of goatgrass. Because the two species are similar enough to cross (but not of the same species), the descendants conserve all the genes from both parents, presenting two genomic pairs.

Wild hybridization of other wheats occurred more than once during the past 14,000 years. Meanwhile, human intervention resulted in the hexaploid species–those having three genetic pairs–including spelt, common wheat, and ultimately modern wheat. Again, einkorn is a diploid, having one genetic pair.

Is einkorn safe for those already with celiac disease?

Unfortunately, einkorn is not recommended for those diagnosed with CD. Initial research results are encouraging however more studies are required. Celiac patients should avoid all types of triticum, including "ancient" species (Suligoj, 2103). However, some studies (Dewar et al , 2006) show that the gluten fragments capable of stimulating T lymphocytes are found in the bulkier gamma-gliadins and glutenins of tetraploid and hexaploid (i.e. modern) wheats. **By comparison, the alpha-gliadins in einkorn tend to lack these harmful peptides** (Spaenji-Dekking et al , 2005). In vitro studies confirm this. Using a mechanical digester (which admittedly doesn't reproduce perfectly the in vivo conditions of human digestion), the processing of einkorn was shown to produce a considerably lower number of harmful peptides (Gianfrani et al , 2015; Spisni et al , 2019).

And while the peptides in spelt exhibited toxic effects during in vitro digestion, those in einkorn did not (Vincentini et al , 2007). Additionally, a study by Suligoj showed that the gliadins of einkorn are sufficiently different from those of modern wheat to have lower immunotoxicity after in vitro simulation of human digestion. As referenced above, einkorn may actually protect against CD. Because it has significantly fewer glutenins than modern wheats,—and because its glutenins have a low immunostimulatory sequence content (Vaccino, 2009)—einkorn may actually enable the prevention of CD in susceptible individuals (Londei, 2005). It's important to note that genetic susceptibility––possessing the recognition molecules HLA DQ2 and/or DQ8 histocompatibility antigens – is a necessary (but not decisive) precondition for a person to actually develop CD. Randomized clinical trials demonstrate that einkorn is less likely to induce the innate pathway of immune response (Picascia et al , 2020; Pizzuti et al , 2006; Zanini & Petroboni, 2013; Zanini et al , 2015). These studies found good clinical tolerance of einkorn in small samples of CD patients compared to modern wheats. This beneficial behavior of einkorn suggests a potential efficacy in patients suffering from other gluten-related disorders, such as non-celiac wheat sensitivity, before NCGS (Spisni, 2019).

Albert Bruno, Nutritionist/Food Scientist

With its unusually high content of beneficial micronutrients,einkorn outperforms hybridized wheat by a wide margin. Here's how it supports immune function(and may exhibitanti-cancer and other effects).

Einkorn about 1 month before harvest

Antioxidant Content

While the nutritional content of food plays an important role in immune response, it's not the only factor. The EFSA (European Food Safety Authority) recognizes that certain micronutrients such as copper, iron, selenium, zinc, folate—and vitamins A, B6, B12, C, and D, among others—contribute to the proper functioning of the immune system. In general, the average concentrations of such micro elements is higher in einkorn than those found in modern tetraploid and hexaploid wheats. einkorn has more iron (3.7-6.2 mg / 100 mg of dry matter), zinc (Hendek 2019), and polyphenols (25% more). It also provides more manganese, copper, strontium, molybdenum, magnesium, phosphorus, and selenium (Dinu et al , 2018), many of which support the normal functioning of the immune system.

Carotenoids

In addition to contributing their characteristic red, orange, and yellow hues to natural products, carotenoids are antioxidants that support healthy immune system function and protect you from disease. Einkorn flour is much higher in these vital nutrients than are modern wheats (Hidalgo & Lucisano, 2019). High performance liquid chromatography (HPLC) reveals that in all triticum species, the yellow pigment is mainly lutein (90%) and to a lesser extent zeaxanthin. This lutein is found in its highest concentration in the germ (32 mg / kg), where it protects the valuable unsaturated fatty acids of einkorn from oxidation, but it's also present in the endosperm (6,3mg / kg) and in the bran (4.3 mg / kg). Refined flour—unless it's stone milled—consists mainly of the starchy endosperm without the germ and bran portions. Consequently, whole einkorn flour shows somewhat higher carotenoid levels than does refined einkorn flour. On a related note, einkorn grains exhibit less lipoxygenase activity than do those of modern wheats (Antognoni et al , 2017) , which could explain the lower degradation of einkorn carotenoids.

Selenium

Selenium is important in both innate and acquired immune systems, and it's an essential support for healthy immune response. Worldwide, more than one billion people suffer from a selenium deficiency (Lyons et al , 2005). While selenium can be found in a wide variety of foods—especially animal-based proteins such as meats, fish, and eggs—plant-based diets are often deficient in selenium if they lack selenium-rich grains. Einkorn provides a far higher selenium content (50.0-54.8 mcg/kg dry matter) compared with conventional wheat varieties (29.8-39.9 mg/kg) dry matter (J. Lachman et al , 2011). In addition to playing an important role in antioxidant function, selenium also acts as a cofactor of some antioxidant enzymes, including reductases and peroxidases such as glutathione. In this way, selenium helps maintain membrane integrity and protects cells from DNA damage. By the same token, selenium deficiency causes a decrease in the production levels of IgM and IgG immunoglobulins (antibodies) by lymphocytes.

Vitamin E

Another essential antioxidant, vitamin E prevents the spread of free radicals formed not only by normal body processes but by exposure to toxic agents such as tobacco or pollution. And einkorn has been shown to contain nearly 50% more vitamin E (69.09 mg / kg) than common wheat (46.57 mg / kg), durum wheat (48.52 mg / kg), emmer (46.37 mg / kg), and spelt (37.10 mg / kg) (Shewry, 2015). Among its many other benefits to human nutrition, vitamin E protects foods such as flours, nuts, and oils from rancidity of its constituent fats. In the body, vitamin E prevents oxidation of low-density lipoproteins (LDL) and cell membranes. Vitamin E also inhibits platelet aggregation and promotes vasodilation, protecting against chronic and degenerative diseases such as cardiovascular disease, cancer, cataracts, and inflammation. In addition, vitamin E improves lymphocyte proliferation and cellular immune memory, increasing the response to infections and supporting immunosenescence. It's helpful to drill a bit deeper into the relationship between vitamin E and einkorn. Tocols—a family of antioxidants—can be broken down into two distinct types: tocopherols and tocotrienols. Tocopherols make up 38% of the vitamin E in einkorn, while tocotrienols make up 62%. Einkorn has 88% more tocotrienol than common wheat (Hidalgo & Brandolini, 2009). While tocopherols are almost exclusively present in the germ, tocotrienols are more abundant in the bran fraction, although significant amounts are present in the germ and in the starchy endosperm.

Free and Bound Polyphenols

Polyphenols are micronutrients that are especially abundant in plants. Of particular interest is their biological role in the potential prevention of major chronic noninfectious diseases including cancer, diabetes, and cardiovascular disease. Among this broad class of compounds, ferulic acid is especially abundant in einkorn. Its flour contains four times as much as common wheat flour, especially in the insoluble/bound form (Antognoni et al , 2017). What's more, the content of free ferulic acid in einkorn bread increases when it's prepared using sourdough starter made from the same flour. As with several other nutrients, experiments utilizing a mechanical digester have detected the presence of ferulic acid in einkorn bread but not in that made from common wheat (Antognoni et al , 2017). Keep in mind that in the human body, microbiota are actively involved in the release of phenolic compounds bound from dietary fiber, thus facilitating their absorption (Dinu, 2018). It follows that there is no linear correlation between the composition and the functional potential of said antioxidants in flour . Shewry et al in 2015 report a total content of polyphenols (836 mg / kg) higher in einkorn than in that of common wheat (750 mg / kg).

Alkylresorcinols

In vitro studies have shown that alkylresorcinols, a group of phenolic lipids, may prevent cells from becoming cancerous (though they don't have any effect on cells that have already become cancerous). Alkylresorcinols also increase gamma-tocopherol levels in rats when fed in high amounts (0.2% of total diet and above) (Ross A. B et al , 2004) In einkorn, the mean content of alkylresorcinols was shown to be higher (595 mcg/g) than in either common wheat (432 mcg/g) or durum wheat (399 mcg/g) (Shewry, 2015).

Phytosterols

Phytosterols and their reduced forms (phytostanols) are sterols of plant origin whose chemical structure is very similar to that of cholesterol. Unlike cholesterol, however, phytosterols aren't synthesized by the human body, so they compete with it for absorption in the intestinal lumen. This inhibition of intestinal cholesterol absorption leads to a corresponding decrease in total circulating cholesterol and LDL, a phenomenon known as the antiatherogenic effect. In brief, it indicates that increased consumption of phytosterols is related to a decrease in the risk of cardiovascular disease. Phytosterols and phytostanols have also been recognized as possessing immunomodulatory properties that could be beneficial in preventing tissue damage associated with inflammation and several cancers (Woyengo et al ,2009). Of all the wheat species, einkorn has the highest concentration of phytosterols, a mean of 1054 mcg /g, about 25% more than common wheat (Shewry, 2015).

POSTPRANDIAL GLUCOSE AND INSULIN LEVELS

A peptide hormone produced by the pancreatic islets, insulin is the main anabolic hormone of the body. Studies suggest einkorn may contribute significant regulatory effects to this crucial metabolic functionary.

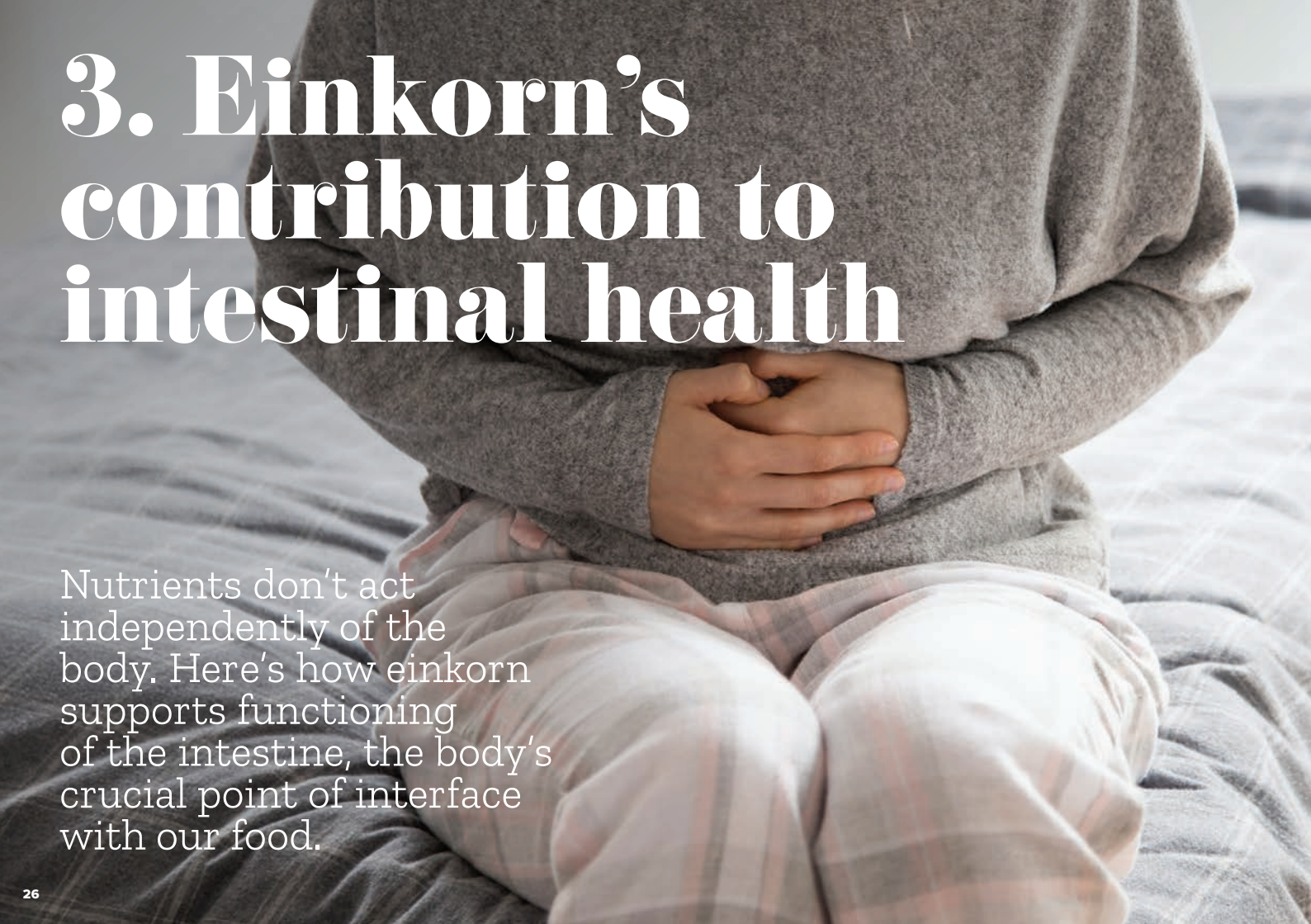
Research on the glycemic effects of ancient whole grains such as einkorn in human and animal diets shows them to have a lower impact on blood glucose, thus helping reduce the risk of type 2 diabetes. A murine study conducted with whole wheat from einkorn and T. dicoccum (emmer) shows how the key genes of glucose metabolism and insulin (a hormone released by the pancreas in response to the elevation of sugar) are downregulated after only 9 weeks of intervention (Thorup et al , 2014). This effect is quite unlike that which occurs with refined common wheat. Maintaining stable glucose levels is another parameter that prevents inflammation (Aune D. et al , 2013). Studies in animal models reveal a bimodal curve with a lower insulin release in the first peak that could prolong the satiety time after the ingestion of einkorn (Barone et al , 2018). The levels of glucose and insulin in the blood after the ingestion of einkorn draw biphasic curves that are lower than those of common wheat, although the difference was only statistically significant for insulin. This correlates with a lower risk of type 2 diabetes in adolescents and adults (Wieser et al , 2009).

To understand the micro effects of carbohydrate consumption on the body, it's useful to understand the glycemic index (GI). The GI is a diagnostic tool used to measure the "effort" made by the body to keep its blood sugar levels stable after ingestion. The faster the starch is digested, the greater the insulin response of the pancreas and the less satiety is obtained (Holt, 1995). Increasing evidence indicates that molecules released either by food or by the microbiota in the intestinal lumen influence the maintenance of glucose levels throughout the body. Biochemical studies show differences between the footprints left by the einkorn-based diet and the common wheat-based diet. With a einkorn-based diet, we see a greater diversity of metabolites and fewer harmful products in the feces, suggesting the development of a different microbiota in the two groups. (Barone f. et al , 2018) In the Bakhøj team's 2013 open-label study on 11 healthy men with a mean age of 25, the glucose-dependent insulinotropic peptide (GIP) only decreased—and significantly so—when einkorn flour was fermented either with salt and honey or with a complete cereal bread crumb. By contrast, GIP did not decrease when the same fermentation scenarios were applied to common wheat flour. It's interesting to note that GIP levels also did not decrease when einkorn flour was fermented with conventional yeast. The authors concluded that starch processing, a type of fermentation, affects the postprandial response of GIP. Why is einkorn so much more beneficial? While clinical studies demonstrate the beneficial behavior of einkorn on glycemic response, we lack a clear explanation for the outcome (Spisni et al , 2019). Some theorize it's related to starch content. The total starch content of einkorn (whole wheat flour) is 60.6% - 71.4%, slightly lower than that of common wheat (63% - 75%) (Hidalgo & Brandolini, 2014). Another possibility is that different methods of processing of grain and flour exert a currently unidentified effect (Barone et al , 2019; Stamaki et al , 2017).

Still another possibility is that the positive effects derive from the synergistic interaction of many factors such as the fermentation process, the food matrix, and the components of the flour that cause intestinal effects. That said, the hypothesis of a different amylose / amylopectin ratio in its starch (analogous to what happens with the different varieties of rice) has not been demonstrated to date (Spisni et al , 2019).

In short, evaluating the benefit of a real food is much more complex than analyzing the sum of its compounds. It is the complete food—not just its constituent parts—that determine the quality and benefits of a dietary pattern. That said, the beneficial effects of incorporating a diet rich in einkorn speak for themselves.

3. Einkorn's contribution to intestinal health



Nutrients don't act independently of the body. Here's how einkorn supports functioning of the intestine, the body's crucial point of interface with our food.

Thus far, we've discussed some of einkorn's many nutrients and constituent components. But of course, to fully grasp the ways this ancient grain exerts its beneficial effects, we need to delve deeper into the story of how, and where, it interfaces with the human body: The intestine.

The intestine is the most important contact and exchange surface in the human body. As such, it's where "the rubber meets the road." The intestine permits the entry of nutrients while simultaneously excluding harmful agents. Four processes make this complex process of "gatekeeping" possible:

1. Peristalsis: The contraction and relaxation of digestive muscles that propagates in a wave. It's the method by which the smooth muscle tissue of the digestive system moves food along. By preventing food from remaining in one spot, the proliferation of harmful bacteria is mitigated and their absorption through intestinal mucosa is limited.

2. Intestinal microbiota: Billions of microorganisms are present in the digestive tract, and all healthy organisms maintain a mutually beneficial relationship with these colonies. The intestinal microbiota contribute to the synthesis and absorption of nutrients, regulate and participate in metabolism, inhibit bacterial invasion, maintain the mucosa, and assist in the development and functioning of the immune system, among many other functions.

3. The epithelial barrier: A membrane that relies on the junctions of its cells to maintain balanced and healthy intestinal "permeability." The epithelial barrier allows nutrients and water to pass into the system while preventing microbial contamination of the interstitial tissue. The functional and anatomical integrity of the barrier can be altered by such factors as inflammation, allergies, infection, autoimmune and metabolic disorders, and even obesity.

4. The intestinal immune system: Containing some 60 - 70% of all the body's lymphoid cells, it provides a defense against harmful microorganisms and in turn supports a tolerance function by preventing excessive responses against food proteins and against bacterial compounds of the intestinal microbiota (Bischoff et al , 2014). With that said, let's examine how einkorn behaves inside this essential bodily organ.

PREBIOTIC EFFECT

Like other wheats, einkorn contains fructans, which contributes to a prebiotic effect. For those who suffer from irritable bowel syndrome, consuming sourdough products may reduce bloating and irritation.

Fructans are small carbohydrates either in the format of short chains (inulin) or very short chains (oligofructose, corresponding to fructooligosaccharides or FOS) These selectively stimulate the growth or activities of beneficial bacteria in the colon, especially bifidobacteria and lactobacilli in what is called the prebiotic effect. It should be noted that not all fiber has this prebiotic effect (O'Grady et al , 2019). For most people, fructans play a very beneficial role. Their prebiotic properties increase the growth of immunomodulators and antioxidants including Bifidobacteria and Lactobacilli. However, a significant proportion of the population experiences difficulty processing fructans. The most common of the chronic functional digestive disorders is irritable bowel syndrome (IBS), which occurs in 3% - 20% of the population. Its diagnosis is based on criteria that associate abdominal pain and or discomfort with intestinal transit disorders without other structural or biochemical abnormalities that would explain them.

People who receive this diagnosis are generally advised to reduce the intake of FODMAPs (Fermentable, Oligo-, Di-Monosaccharides, and Polyols) in order to limit the presence of small "sugars," i.e. compounds not absorbed by the digestive system which instead ferment excessively in the intestine, causing gas and digestive discomfort (Biesiekierski, 2013). Some studies suggest that flour made from einkorn has a higher fructan content compared with other types of wheat flour. However, the simple precaution of increasing the dough's resting time beyond four hours effectively reduces the fructan load in the final product by as much as 90% (Muir J et al , 2019).

POTENTIAL BENEFICIAL EFFECTS ON THE MICROBIOTA

Research indicates that a diet high in einkorn could support a greater diversity of health-promoting bacteria and intestinal health.

Human gut microbiota is involved in multiple metabolic processes in addition to the balance of the intestinal immune system (GALT). Wheat proteins such as gluten and ATIs are only partially digested by proteases, but they can be efficiently degraded by the intestinal microbiota in a complex interaction that affects both the immunogenicity of the peptides and the composition of the microbiota, which in turn reduces the risk of developing wheat-related disorders (Spisni, 2019).

Human studies show changes in the genuses and species of different bacteria based on whole wheat consumption. A diet rich in fruits, vegetables, and whole grains has been linked to high levels of bacteroidetes, which are particularly effective in the production of short chain fatty acids (SCFA), which in turn protect the mucosa and dampen intestinal inflammation (Vitaglione P. et al , 2015). Research on pigs shows that a einkorn-based diet could modulate the intestinal ecosystem in its composition and at the metabolic level toward a configuration specifically enriched in health-promoting bacteria and with greater bacterial biodiversity, supporting greater balance (eubiosis) and intestinal health (Barone F. et al.2018).

Why pigs? Multiple studies show that the composition of their intestinal microbiota is similar to that of humans. These animals present significant physiological and anatomical similarities to humans. They are also omnivores,have a similar intestinal transit time, and demonstrate very similar digestive and absorptive processes.

The polyphenols present in the vegetables that both pigs and humans eat are activated

by a healthy microbiota in the intestine. Einkorn was shown to increase species of intestinal bacteria such as *Faecalibacterium*[1], *Oscillospira*[2], the genus *Blautia*[3], or the phylum *Bacteroidetes* that in turn produce short-chain fatty acids. These maintain the intestinal mucosa and reduce inflammation. As an example, the proportion of *Bacteroidetes* (B) with respect to *Firmicutes* (F) also increases, going from an F / B index of 5.58 to 3.25 in just one month (Barone F. et al , 2018).

These results point to a powerful prebiotic benefit of einkorn in which its consumption modulates the intestinal microbial profile towards a configuration less prone to inflammation and richer in bacteria that contribute to the health of the host. The effects could derive from the synergy between the fermentation process, the food matrix, or the composition of the flour (Barone F. et al , 2018). Although more studies are needed, the potential anti-inflammatory effects of the consumption of einkorn show great promise (Barone F. et al , 2018).

Revival Einkorn pasta for lunch.

AMYLASE-TRYPSIN INHIBITORS (ATIS)

These proteins defend plants from parasites, but they can also trigger non-celiac gluten sensitivity. Here's how einkorn reduces these natural irritants.

In the same way that celiac disease isn't the only disease triggered by gluten, gluten isn't the only family of proteins with immunogenic potential and negative effects on the intestine. Research is currently being conducted to understand the possible involvement of amylase-trypsin inhibitors (ATIs) in the activation of the innate immune system (unlike celiac disease) and the symptomatic display in those diagnosed with non-celiac gluten sensitivity (NCGS) . ATIs constitute a family of up to 17 low molecular weight proteins that represent up to 4% of the protein content of common wheat flour. These proteins are highly resistant to digestion by intestinal proteases. ATIs play a role in the maturation of the wheat endosperm (flour) and in defending the plant from parasites.

As it relates to ATIs, what makes einkorn flour unique is the absence or minimal presence of certain wheat molecules with an inhibitory effect on enzymes that interfere with digestion, specifically human amylases and trypsin. This effect blocks the hydrolysis of starch and proteins, disturbing the digestive process and manifesting in symptoms derived from the presence of gasses: bloating, pain, and extra-digestive effects (headache, chronic fatigue, and depression). In one study, ATIs were detected in only three of eight einkorn cultures, and these in very low quantities. In the other five they were imperceptible (Geisslitz S. et al , 2018) As we've noted before, not all wheats are the same. Nor are all "ancient grains" the same. Ancient wheats other than einkorn contain greater quantities of ATIs. Because ATIs serve to defend the plant against parasites, it's theorized that einkorn's spike and hard shell are effective enough to render ATIs unnecessary (or at least less necessary) to the plant (Geisslitz S. et al , 2018). The important takeaway is that as far as ATIs are concerned, ancient wheats do not constitute a homogeneous category (Bordoni et al , 2017). Nor is einkorn's lower ATI content compared with other wheat species—emmer, durum, khorasan, spelt, and common—the only distinguishing factor here. With the curious exception of spelt, the expression of ATIs seems to increase with ploidy (Zevallos, 2017). This, combined with einkorn's higher total protein, lower total gluten, and gluten of a much weaker structure, reinforces the position that it has overall greater digestibility (Spisni, 2019; Igbinedion et al , 2017; Spisni et al , 2019).

SOLUBLE AND VISCOUS FIBER

Einkorn's high fiber content makes it a great candidate for those seeking to improve their metabolism, their digestion, and their overall well-being.

Dietary fiber is not a single substance but a heterogeneous group of mainly plant-based substances. In the human intestine, fiber exerts multiple biological effects, undergoing microbial digestion through anaerobic fermentation.

Fiber is key to keeping the digestive tract healthy. It helps create a pleasant feeling of satiety, nourishes the microbiota, and maintains intestinal transit. Fiber is classified according to its solubility, viscosity, and fermentability properties, which allow us to understand its various health effects. Solubility refers to its dissolution in water, but it is the viscosity (ability to form gel with water) of some fibers that influences the consistency of the bolus and slows the rate of digestion and absorption by digestive enzymes.

Fiber also regulates the absorption of some nutrients (lipids and sugars) contributing positively to your metabolism. Most foods contain both soluble and insoluble fiber. The total dietary fiber content of einkorn is around 10% of the dry matter, in contrast with 11.5 - 18.3% of the weight of common wheat (Hidalgo & Brandolini, 2014).

Insoluble fiber components (cellulose, hemicellulose fractions, and lignin) exert a laxative effect by stimulating and irritating the intestinal mucosa to increase secretion and peristaltic movements. The greater the length and thickness of the dietary fiber particles, the greater the effect on stool volume and the shorter the intestinal transit time. Einkorn has been shown to have a higher percentage of lignin—which is not a carbohydrate but is considered a non-soluble fiber—than other wheats, including some ancient grains (durum, emmer, and spelt) (Shewry, 2015). Lignins are present in significant amount in plants and play a protective role against the development of several diseases (obesity, diabetes, thrombosis, etc.) thanks to their antioxidant capacities (Vinardell M. et al , 2017)

LIPID PROFILE

Einkorn's low saturated fat content may aid in the prevention of cardiovascular disease.

We know that diet plays a major role in the prevention of cardiovascular diseases. Unsaturated fatty acids contribute to the synthesis of cholesterol and lipoproteins, thereby reducing the risk of thrombosis and atherosclerosis. Because lipids represent a minor part in the nutritional composition of common wheat, its inclusion isn't typically decisive in a sufficiently varied diet (Hidalgo A., Brandolini A, 2014). However, the high proportion of fatty acids in einkorn makes it highly suited in this regard. Additionally, having more mono-unsaturated and fewer polyunsaturated fats lengthens the useful life of the flour (Hidalgo A., Brandolini A., 2014).

Although einkorn germ and common wheat germ are similar, einkorn contains almost 50% more fat than common wheat (4.2% of dry weight vs 2.8%) (Hidalgo & Brandolini, 2009). One contributing factor is that einkorn's grain is significantly smaller, thereby increasing the proportional contribution the bran makes to the grain's nutritional components.

In the einkorn grain, approximately half of total lipids are linoleic acid (omega 6, polyunsaturated), a quarter are oleic acid (omega 9, monounsaturated) and approximately 15% is palmitic acid. Small amounts of linolenic (omega 3) and short-chain fatty acids make up the remainder. In common wheat, linoleic acid is also the most prevalent (57%), but a higher concentration of saturated fat (palmitic, 21.3%) reduces the percentage of monounsaturated (oleic, 15.4%). As with einkorn, environmental factors such as soil, climate, fertilizers, etc have an impact as well (Righetti et al , 2016).

4. Other Aspects of Einkorn's Nutritional Profile

In addition to the aforementioned nutrients, einkorn provides significant amounts of proteins, vitamins, and minerals to a well-balanced diet.

As the preceding sections have made clear, einkorn is distinguished among grains by an unusually high nutritional content. In addition to its abundant content of minerals, vitamin E, and phytosterols, it has an excellent lipid profile. This makes it an outstanding candidate for inclusion in diets requiring enhanced protein: weight control, vegetarian and vegan, childhood and adolescence, athletic, pregnancy and lactation, convalescence from interventions and burns, prevention of sarcopenia, and cancer recovery, to name a few examples.

In this section, we'll explore a few of the remaining aspects of einkorn's overall nutritional value and contribution to a healthy and well-balanced diet.

Chart Sources: 1) USDA National Nutrient Database for Standard Reference, Release 22. http://www.ars.usda.gov/main/site_main.htm?modecode=12-35-45-00 2) "Chemical composition and pasting properties of einkorn (Triticum monococcum L. subsp. monococcum) whole meal flour." A. Brandolinia, , A. Hidalgob, S. Moscaritolo. Journal of Cereal Science 47 (2008) 599–609 3) "Variation in mineral micronutrient concentrations in grain of wheat lines of diverse origin." F.J. Zhao, Y.H. Su, S.J. Dunhama, M. Rakszegi, Z. Bedo, S.P. McGrath, P.R. Shewry. Journal of Cereal Science 49 (2009) 290–295 4) "Compositional and Nutritional Characteristics of Spring Einkorn and Spelt Wheats." E.-S. M. ABDEL-AAL. P. HUCL and F. W. SOSULSKI. Cereal Chem. 72(6):621-624

NUTRITIONAL QUALITIES OF GRAINS

	Einkorn Wheat	Kamut Wheat	Spelt Wheat	Triticale Wheat	Rye Wheat	Oats	Barley (pearled)	Wheat (hard white)	Wheat (soft white)	Wheat (hard red winter)	Wheat (hard red spring)	Wheat (soft red winter)	Durum Wheat	Rice (brown, long-grain)	Corn (maize, yellow)	Corn (maize, white)	Sorghum	Millet
Proximates																		
Water (g)	no data	10.95	11.02	10.51	10.6	8.22	10.09	9.57	10.42	13.1	12.76	12.17	10.94	10.37	10.37	10.37	9.2	8.67
Energy (kJ)	1450	1411	1414	1406	1414	1628	1473	1431	1423	1368	1377	1385	1418	1548	1527	1527	1418	1582
Protein (g)	18.2	14.7	14.57	13.05	10.34	16.89	9.91	11.31	10.69	12.61	15.4	10.35	13.68	7.94	9.42	9.42	11.3	11.02
Fat (g)	2.48	2.2	2.43	2.09	1.63	6.9	1.16	1.71	1.99	1.54	1.92	1.56	2.47	2.92	4.74	4.74	3.3	4.22
Carbohydrate (g)	no data	70.38	70.19	72.13	75.86	66.27	77.72	75.9	75.36	71.18	68.03	74.24	71.13	77.24	74	74.26 7	4.63	72.85
Fiber (g)	8.7	9.1	10.7	no data	15.1	10.6	15.6	12.2	12.7	12.2	12.2	12.5	no data	3.5	no data	no data	6.3	8.5
Sugars (g)	2.67	8.19	6.82	no data	0.98	no data	0.8	0.41	0.41	0.41	0.41	0.41	no data	0.85	0.64	0.64	no data	no data
Vitamins																		
Thiamin (mg)	0.5	0.591	0.364	0.416	0.316	0.763	0.191	0.387	0.41	0.383	0.504	0.394	0.419	0.401	0.385	0.385	0.237	0.421
Riboflavin (mg)	0.45	0.178	0.113	0.134	0.251	0.139	0.114	0.108	0.107	0.115	0.11	0.096	0.121	0.093	0.201	0.201	0.142	0.29
Niacin (mg)	3.1	6.35	6.843	1.43	4.27	0.961	4.604	4.381	4.766	5.464	5.71	4.8	6.738	5.091	3.627	3.627	2.927	4.72
Pantothenic acid (mg)	no data	0.905	1.068	1.323	1.456	1.349	0.282	0.954	0.85	0.954	0.935	0.85	0.935	1.493	0.424	0.424	no data	0.848
Vitamin B-6 (mg)	0.49	0.255	0.23	0.138	0.294	0.119	0.26	0.368	0.378	0.3	0.336	0.272	0.419	0.509	0.622	0.622	no data	0.384
Folate (mg)	no data	no data	45	73	38	56	23	38	41	38	43	41	43	20	19	no data	no data	85
Vitamin E (mg)	no data	0.6	0.79	0.9	0.85	0.7	0.02	1.01	1.01	1.01	1.01	1.01	no data	1.2	0.49	no data	no data	0.05
Carotene, beta (µg)	19	5	5	no data	7	no data	13	5	5	5	5	0	no data	0	97	no data	no data	no data
Carotene, alpha (µg)	53	2	0	no data	0	no data	0	0	0	0	0	0	no data	0	63	no data	no data	no data
Vitamin A (IU)	312	10	10	0	11	0	22	9	9	9	9	0	0	0	214	0	0	0
Lutein +zeaxanthin (µg)	769	301	169	no data	210	no data	160	220	220	220	220	0	no data	0	1355	no data	no data	no data
Tocopherol, beta (mg)	no data	0.15	0.25	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	0	no data	no data	no data	no data
Tocopherol, gamma (mg)	no data	1.15	1.71	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	0	no data	no data	no data	no data
Tocopherol, delta (mg)	no data	0.01	0	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	0	no data	no data	no data	no data
Vitamin K (phylloquinone)	no data	1.8	3.6	no data	5.9	no data	2.2	1.9	1.9	1.9	1.9	no data	no data	1.9	0.3	no data	no data	0.9
Minerals																		
Calcium (mg)	no data	24	27	37	24	54	29	32	34	29	25	27	34	23	7	7	28	8
Iron (mg)	4.59	4.41	4.44	2.57	2.63	4.72	2.5	4.56	5.4	3.19	3.6	3.21	3.52	1.47	2.71	2.71	4.4	3.01
Magnesium (mg)	no data	134	136	130	110	177	79	93	90	126	124	126	144	143	127	127	no data	114
Phosphorus(mg)	415	386	401	358	332	523	221	355	402	288	332	493	508	333	210	210	287	285
Potassium (mg)	390	446	388	332	510	429	280	432	435	363	340	397	431	223	287	287	350	195
Sodium (mg)	no data	6	8	5	2	2	9	2	2	2	2	2	2	7	35	35	6	5
Zinc (mg)	2.24	3.68	3.28	3.45	2.65	3.97	2.1	3.33	3.5	2.65	2.78	2.63	4.16	2.02	2.21	2.21	no data	1.68
Copper (mg)	no data	0.522	0.511	0.457	0.367	0.626	0.4	0.363	0.4	0.434	0.41	0.45	0.553	0.277	0.314	0.314	no data	0.75
Manganese (mg)	4.4	2.86	2.983	3.2	2.577	4.916	1.3	3.821	3.4	3.985	4.055	4.391	3.3012	3.743	0.485	0.485	no data	1.632
Selenium (mg)	27.89	69.3	11.7	no data	13.9	no data	38	no data	no data	70.7	70.7	no data	89.4	23.4	15.5	15.5	no data	2.7

PROTEINS

With its high (and uniquely digestible) protein content, einkorn is especially suited for those on plant-based or other restrictive diets.

Einkorn berries contain a higher percentage of proteins than do those of common wheat. Compared with a mean value of 12.1 gr / 100 gr dry matter, einkorn's mean value is 18.1 grams per 100 grams of dry matter (Hidalgo & Brandolini, 2009). Previously, Abdel Aal in 1995 found an average protein content of 16.7% when investigating 15 different strains of einkorn.

Evaluating just the endosperm (the grain body or "white flour"), it's been found that einkorn's protein content is 15.4% - 25.2% higher than common wheat's (Corbellini et al , 1999). This range is due to the wide genetic variance among einkorn examples (Hidalgo & Brandolini, 2014).

Finally, as outlined earlier, it's important to note that einkorn possesses different—and more digestible—gliadin and glutenin types than modern wheat, and contains a reduced number of epitopes and toxic peptides (Di Stasio et al, 2020).

AMINO ACIDS

Overall, the amino acid composition of einkorn's proteins are very similar to those of modern wheats. However, when adjusted for its relatively higher protein level, its content of essential amino acids—those the body cannot obtain other than from direct intake of food—is slightly superior. (Brandolini et al , 2011). Given the protein requirements of the specialized diets listed a moment ago, these differences should be a significant factor when considering the type of flours and foods to be included.

B VITAMINS

Compared with common wheat, einkorn has more thiamine (B1), pyridoxine (B6), and four to five times more riboflavin (B2) (Abdel-Aal, 2005). Folic acid (B9) content—critical for both pregnant women and their fetuses—is found in similar amounts in both einkorn and common wheat (Hidalgo A. and Brandolini A., 2013).

ZINC AND IRON

Essential players for overall immune function, these minerals are found in abundance in einkorn. Zinc directly affects the maturation of lymphocytes, a type of white blood cell that plays a critical role in the immune system. What's more, zinc is involved in the activity of more than 200 enzymes, and plays an important role in maintaining the integrity of the intestinal mucosa. Iron is another essential mineral. Your body uses it to make hemoglobin—a protein in red blood cells that carries oxygen from the lungs to all parts of the body—and myoglobin, a protein that provides oxygen to muscles. Deficiencies in either zinc or iron can cause major health problems, including the deterioration of the immune system, the failure of growth or of mental and cognitive development, and an increase in the rates of anemia, morbidity, and mortality.

Cereals represent the primary source of zinc and iron for the inhabitants of many countries, particularly those in the developing world. But because cereals are inherently poor in both the content and bioavailability of these micronutrients, almost half of the world's population experiences some kind of deficiency.

Here again, einkorn may provide an answer. Because of the small volume of its grain, einkorn's bran is more prominent than in modern wheats, concentrating both trace elements and fiber. For this reason, einkorn is much richer in magnesium, phosphorus, selenium, and zinc compared with common wheat. (Hidalgo A. and Brandolini A, 2013)

As we'll explore more fully in a moment, wheat's micronutrient and phytochemical contents are influenced both by its genetics and also by its environment and the interaction between the two (Dinu, 2018). In general, the average concentrations of einkorn's microelements, including iron (3.7-6.2 mg / 100 mg of dry matter) and zinc (4.2-7.1mg / 100g of dry matter), are higher than hexaploid wheats such as T. aestivum (Hendek, 2019; Hidalgo and Brandolini, 2014). The same goes for manganese, copper, strontium, molybdenum, and magnesium, phosphorus, and selenium (Dinu et al , 2018), many of which—like iron and zinc—support healthy immune system function.

VITAMIN A

In addition to providing generalized immune system support, this vitamin protects cells and tissues from free radicals. In addition, they contribute to anticancer and other protective effects.

We discussed carotenoids earlier, the natural pigments that provide significant antioxidant power to the body. Because they're soluble in fat, they're readily absorbed and accumulate in the body's adipose tissue including the liver, lungs, spinal cord, skin, prostate, and kidneys. Carotenoids—especially lutein and zeaxanthin—are also deposited in the macula lutea, the pigmented area in the center of the retina. The presence of carotenoids here positively correlates with the prevention of both macular degeneration and cataracts (Buscemi et al , 2018). This is why lutein is sometimes known as "the eye vitamin," and we'll explore its story more fully in a moment. Only the carotenoids alpha and beta carotene participate in the synthesis of vitamin A, essential for synthesis of rhodopsin in the photoreceptors of the retina. This is crucial for cell differentiation, growth, and development, as well as generalized support of the immune system. They all have in common the protection of cells and tissues from free radicals, and thus contribute to the maintenance of structures related to vision, the inhibition of certain cancers (stomach, lung, and skin), and the prevention of cardiovascular and degenerative diseases.

LUTEIN

Einkorn is especially rich in this nutrient, popularly known as "the eye vitamin." One of the two major carotenoids found in the human eye, lutein is believed to function as a light filter, protecting the macula and retina from sun damage.

When it comes to lutein content, einkorn is unrivaled in the grains (Atognoni et al , 2017). Among the ancient wheats, cultures of einkorn, khorasan (T. turgidum ssp turanicum) and emmer showed the highest lutein (7.28, 4.9 and 2.7 mg / kg) and carotenoid contents (2.26, 6.65, and 8.23 mg / kg = micrograms / gram of dry matter respectively). And while lutein is the most prominent carotenoid in wheat, several lines of einkorn have been shown to contain 3 - 8 times more lutein than common wheat, and 2 times more than durum wheat. The endosperm of einkorn contributes the majority of its lutein (76.6%) (Brandolini A. and Hidalgo A., 2011) and provides a quarter of the total tocols. This, among other findings, suggests that even refined einkorn flour still retains excellent nutritional value.

Einkorn for generational health.

5. Miscellaneous Factors

Regenerative farming for soil health.

Thus far, we've discussed einkorn's protein, mineral, antioxidant, and fiber content. In this section, we'll cover a few points relating to how factors such as cultivation and baking affect products made from its grains and flour.

ENVIRONMENT AND PROCESSING

Naturally pest-resistant and drought-tolerant, einkorn exerts a far lower toll on its growing environment than does modern wheat. And its unique processing demands may actually help it preserve precious nutrients and fiber.

Grown under identical conditions, the micronutrient load of einkorn is superior to that of any modern wheat. However, environmental conditions play a role, and it would be possible for modern wheats to greatly improve their micronutrient content if they were grown in superior soils. In practice, however, they typically aren't. As a result, the vast majority of modern wheat is cultivated on nutritionally depleted soils.

Nor is a supportive growing environment enough. A recent study determined that environmental and genetic factors don't operate in isolation from one another. Rather, the interaction between the two can have a significant effect on the quality of the final product (Dinu, 2018). The vast majority of modern wheats are grown, harvested, and processed using industrial farming techniques. By comparison, einkorn is almost exclusively cultivated in an ecologically sound and regenerative way, which produce very fine flours.

This process generates heat, which degradates vitamins, essential fatty acids, and some amino acids. In comparison, mills that grind einkorn typically use stone cylinders to process the grain. These generate much less heat than do metal cylinders, and also produce larger particles (sizes 1 and 2). The resulting flour is less refined, which conserves elements of the whole grain such as the fiber-rich bran. Thus, in addition to other health benefits, this helps to achieve a lower glycemic index.

Einkorn flour is often fermented with sourdough (Lactobacilli). This fermentation requires a long time to begin the "digestion" of proteins such as gluten, ATIs if present, and carbohydrates, as well as supporting the bioavailability of micronutrients. This process has been shown to result in a more digestible gluten and reduce its immunogenic and fructan loads (Spisni et al , 2019).

THE BAKING PROCESS

An important piece of the "nutrition puzzle" is that baked bread contains higher concentrations of macro and micro nutritional compounds than does its constituent flour (Van Boxstael et al , 2020). In addition, the use of fermentation, for instance in sourdough products, better protects against the degradation of carotenoids caused by the lipoxygenase activity in food products. As noted earlier, einkorn has a lower lipoxygenase activity than do other wheats, and this could help explain the higher carotenoid content in einkorn bread, up to 4 times more, compared with those made with common wheat. (Antognoni et al, 2017).

ANTIOXIDANTS

Antioxidants are compounds that inhibit oxidation, a chemical process that can produce destructive chain reactions in the body's cells. With an abundant content of antioxidants such as lutein, selenium, the carotenoids, bound polyphenols, tocols, alkylresorcinols, phytosterols and others, einkorn flour is superior in many aspects compared to that of other wheats (Hidalgo & Brandolini, 2006 & 2009). What's more, the low activity of its beta-amylase and lipoxygenase enzymes, which protect against degradation during grain processing, also contribute to einkorn flour's utility.

WHEAT COMPARISON TABLE

Wheat characteristics	T. monococcum	T. turgidum spp dicoccum	T. turgidum spp durum	T. turgidum turanicum	T. aestivum spp spelt	T. aestivum spp aestivum
Common name and number of chromosomes	Einkorn, "mother of all wheat" diploide	Emmer, wheat of the pharaohs, twin spelled, "Farro" in Italy, tetraploid	Durum pasta wheat, tetraploid	Kamut, khorasan wheat, tetraploide	Spelt, hexaploide	Common wheat, soft, bread, modern, hexaploid
Protein	Contains the most protein of any wheat (18g per 100g of flour)	High in protein, very nutritious, used in Ethiopia for pregnant women	13.69g per 100g of flour	14.54g per 100g of flour	Higher protein content than common wheat with similar gluten composition but poorer baking quality	Lowest protein content: 10.69g per 100g of flour
Glutenins (range between 60-80 mg per gram) Bulky and heavy (Kda). Insoluble. They give elasticity and toughness dough.	Einkorn has the lowest content of glutenins, and most of them are also of low molecular weight.	Low gluten levels (range can vary)	Lower glutenin content than common wheat and spelt.	Lower glutenin content than common wheat and spelt.	Higher content of gluten and glutenins than common wheat.	High content of glutenins
Gliadins/glutenins (Koehler et al. Foods.2019;8(9):409. Flour quality or baking aptitude.	Glia/glut=5-8. Very digestible. All varieties are suitable for baking and some varieties are good for bread and pasta making.	Glia/Glute = 4-6. Very digestible. Good for bread, suitable for semolina and pasta.	Glia/glut = 3-6 ideal for pasta.	Glia/glut = 3-6 Bread and baked goods	Glia/Glut=3-4 Absence of gliadin omega makes it harder to digest. Good for bread, baked goods and pasta.	Glia/Glut= 2-3 Poor digestibility. Excellent for bread and baked goods.
Carbohydrates	65% lower starch than othe wheats.	Less digestive starch?	71g carbohydrates per 100g of flour	71g carbohydrates per 100g of flour, but almost 8g correspond to free sugars (Valli et al. Int J Food Sci Nutr. 2017)		Highest % of starch. 75g carbohydrates per 100g of flour
Fat	Richest in lipids (50% more) with more monounsaturated (53% +) and less Q saturated (20%-) than common wheat. anti-inflammatory effect+		2.47g per 100g of flour	2.13g per 100g of flour	Higher lipid content and higher % of AGI than common wheat	Low in fat (2.8%) and also higher % of saturated lipids. 2g per 100g of flour
Carotenoids (Lutein): Vitamin E, Polyphenols, Alkyresorcinols	The richest in carotenoids (460%+): Vitamin E (46%+), >bound polyphenols, >bound ferulic (x4BW), >alkyneorcinols. antioxidants, anti-inflammatory+++	Rich in carotenoids, rich in antioxidants, total phenols and flavonoids.	50% less lutein and alkyresorcinols than einkorn	Vitamin E only .6mg per 100mg of flour	More Vitamin E, A and B than common wheat.	<Carotenoids, less lutein <Conjugated polyphenols, less ferulic bound <alkyredorcinols.
Phytosterols (inhibit cholesterol absorption)	Rich in phytosterols					Very low in phytosterols
Minerals	Higher content of iron, zinc, magnesium, selenium and lower content of cadmium than common wheat.	Rich in minerals but also aphitic (chelating)	Iron: 3.5mg, Zn:4.16 mg, Calcium:34mg per 100g of flour	Iron: 3.77mg, Zinc: 3.68, Calcium: 22mg per 100g of flour	Richer in minerals than common wheat, especially in the bran	Iron: 5.37mg, Zinc 3.48mg, Calcium:34mg per 100g of flour
Enzymatic activity	Lower alpha- and beta-amylase activity than T turgidum and T aestivum. Lower lipoxygenase activity than durum or aestivum.					> Enzymatic activity alpha- and beta- amylase and lipoxygenase
ATIs (antigens) Presence/absence of hard covers	Absence or minimum amount of ATIs. Dressed wheat with a protective hull. It grows in areas where other wheats do not survive, very low impact.	ATIs>5 Dressed wheat. Very resistant to diseases. Some varieties are more tolerant of high salinity soils.	ATIs>4 Naked Wheat Fructans:1.17%	Naked Wheat	High load of ATIs. Dressed wheat. Does not require herbicides, fertilizers, fungicides or pesticides.	Loaded with antigens (ATIs) (4% of the total protein). Pesticides in non-organic crops. Highly processed.
Dietary Fiber, Fructans (prebiotic activity: beneficial effects on the microbiome)	Fiber :10%, Fructans: 2% (effective prebiotic++)	More fiber than common wheat Fructans: 0.95%			Less fiber than common wheat Fructans: 1.26%	Fiber 11.5-18.3% Fructans 1.57% per 100g flour

6. Conclusions

As we've seen, einkorn played an essential role in the story of agriculture. But while it was sidelined by modern wheat varieties and their higher yields, current understanding of human (and planetary) health makes this an ancient grain worth a second look.

Einkorn is a hugely important plant in the human story. In addition to being the first cultivated wheat we have evidence of, there is a high probability that it was in fact the first foodstuff cultivated by humans. It was actively grown in the Fertile Crescent at least 12,000 years ago, though archaeological findings indicate that wild einkorn was consumed long before then.

That said, einkorn experienced a decline in popularity, due in large part to the higher yields associated with modern wheats. It's only thanks to the care and dedication of a few farmers in far-flung regions of the planet that einkorn has managed to survive. But it's high time that its unusual content of proteins, carotenoids, minerals, antioxidants, and other bioactive compounds garner greater attention. On top of providing exceptional nutritional value to those on unrestricted diets, einkorn is recommended for those on a plant-based or plant-primary diet. What's more, it's been shown to be appropriate for children (Brandolini et al , 2008), those who consume functional foods (Lombardo et al , 2015), and many other populations with special dietary needs.

Admittedly, because it is a "dressed wheat"—that is, protected by a shell—einkorn requires more arduous and expensive processing than does modern wheat. That said, the robustness of its hull also translates into greater resistance to parasites as well as a better adaptability to arid terrain and inclement weather. In a world challenged by rising temperature and changing precipitation patterns, these are significant advantages for this hardy grain.

Einkorn develops a gluten of completely different quality compared to modern wheat's. Its structure is weaker, less toxic, and thus more digestible and non-inflammatory. Its unique structure and the synergy between its components give it an anti-inflammatory power unique among wheats. And einkorn's relatively small size yields a higher bran-germ / endosperm ratio, partially explains its high concentration of phytochemicals and micronutrients.

What's more, einkorn shows very little or imperceptible presence of ATIs, proteins believed to be associated with non-celiac gluten sensitivity (NCGS). Thus, einkorn is suitable for a great majority of people who suffer from NCGS, a clinical finding supported by ample anecdotal evidence. Other studies suggest that the microbiota of animals fed einkorn versus modern wheat become enriched with beneficial bacteria. These in turn produce short-chain fatty acids with greater microbial and metabolic diversity, suggesting a potent prebiotic effect for gut ecosystem and health. Einkorn is also an ideal species for genetic research on wheat quality. Its simple diploid genome encodes fewer immunoreactive elements and although it is not suitable for those who suffer from celiac disease, it is suitable for people with NCGS or irritable bowel syndrome among other digestive system inflammatory pathologies. In conclusion, it should be clear by now that einkorn is a very different wheat from the ones most modern-day humans are familiar with. In addition to its exceptional nutritional content and its suitability for regenerative and sustainable farming techniques, its superior digestibility makes it a strong candidate as a replacement for nutritionally deficient modern flours. If history can be seen as the progression of science and empirical knowledge towards a healthier and more enlightened state of being, einkorn is the exception that proves the rule. One might say "nature got it right the first time," a sentiment echoed by anyone who's ever tasted this remarkable and healthful grain.

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