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Innovative beer-brewing of typical, old and healthy wheat varieties to boost their spreading

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ABSTRACT

Brewing with large fractions, up to 100%, of raw unmalted grains from certain Mediterranean old wheat varieties, is experimentally shown to be technically feasible, leading to beers retaining all the basic features of traditional products, as well as showing potentially healthy qualities, in terms of total polyphenol content and antioxidant activity, comparable to 100% barley malt beers. Beer has become the worldwide most consumed alcoholic beverage and, although few global players and standardized products dominate its market, craft breweries have quickly spread out in many countries. Nevertheless, severe issues have arisen about the economic sustainability of microbreweries, mainly due to high initial capital investment, energy costs, scale, and sometimes taxation. Recently, a breakthrough, cheaper, and more efficient brewing technology based on controlled hydrodynamic cavitation has been introduced, whose applicability to raw unmalted grains from typical old wheat varieties is experimentally demonstrated, leading to results comparable with traditional techniques but at a fraction of the cost, opening a new way to increase the profitability of craft microbreweries. In turn, profitably brewing a fraction of old wheat varieties could represent a viable support to the upscaling of the respective cultivation, the latter representing a necessary condition to relieve the economic sustainability issues and improve the environmental sustainability. Along with the high, renowned nutritional and healthy value of certain old wheat varieties in comparison to modern ones, their spreading could contribute to both lowering the environmental footprint of the cereal sector and improving the public health, as well as contributing to a prospective and environmentally very favorable shift of the human diet from animal-source proteins to plant-source proteins.

1. Introduction

It has long been known that shifts in food production and consumption, involving cereals, generate profound effects upon many categories of the environmental burden of the agricultural and food sector. An updated review of the present state of the art was offered by the special volume of the Journal of Cleaner Production entitled "*Towards eco-efficient agriculture and food systems*", whose articles, along with many previous ones, were comprehensively reviewed by Sala and co-authors (Sala et al., 2017).

Italian authors investigated farming practices leading to minimization of the environmental burden from rainfed durum wheat cultivations under Mediterranean conditions (southern Italy), finding that a minimization of soil operations (no tillage), coupled with a suitable rotation with nitrogen-fixing legume crops, could increase the wheat yields and improve most categories of the environmental impact (Ali et al., 2015).

Lately, the same authors found that under optimized farming practices, including reduced nitrogen fertilizing and suitable rotation, the greenhouse gases (GHG) emissions could be lowered by over 70% both per unit area and per kilogram of produced wheat, with respect to conventional farming (Ali et al., 2017). Their results highlighted the wide room left for decisive improvements at the

Abbreviations: AOC, antioxidant compounds; ARG, antibiotic-resistant genes; BIAB, brew in the bag; CN, cavitation number; EBC, European Brewery Convention; EU, European Union; FRAP, Ferric ion Reducing Antioxidant Parameter; GHG, greenhouse gases; HC, hydrodynamic cavitation; LCA, Life Cycle Assessment; SG, specific gravity; SRM, Standard Reference Method.

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farming level, and showed consistency with another study concerning a farmers' cooperative in north-eastern Italy (Fantin et al., 2017).

A recent study compared the production of equivalent amounts of animal-source proteins obtained from intense farming, and plant-source proteins, showing that the former production model was much more expensive in terms of land area (2.4–33 times) and GHG emissions (2.4–240 times) (Di Paola et al., 2017). The main reason for such striking differences was found in the very limited conversion rate – around 15% - of plant-source proteins into animal-source ones available for human consumption in the respective production model, leading the authors to advocate a widespread compression of livestock-dedicated cultivations, mainly cereals and legumes, while increasing the respective production for direct human consumption. The same authors pointed out that adequate intake of plant-based proteins in the human diet could be achieved by suitably combining cereals and other protein-rich crops such as legumes, thereby matching the important above-described requirement for further reducing the environmental footprint of low-input durum wheat cultivations (Ali et al., 2017, 2015). Overall, it appears that the combination of low-input farming with a shift in consumers' habits, could allow cutting GHG emissions down to a small fraction, likely even around 1%, as well as land consumption, the latter down to 10% or less, compared with current figures.

In another paper of the above-mentioned special volume, Sonesson and co-authors introduced more advanced functional units than the simple mass-based one, *i.e.* "gram protein", "gram digestible protein" and a more complex unit involving the digestible intake of the nine essential amino acids (Sonesson et al., 2016). Because of the new normalizations, the assessment of few key environmental impact categories for different food products, such as global warming potential, land use and freshwater ecotoxicity, clearly improved after accounting for the products' nutritional value. However, neither the impact upon the public health, along with connected environmental and economic costs, nor additional food properties contributing to a healthy diet, such as antioxidant compounds and activity, were considered.

In a further article of the same special volume, authored by Spanish scholars, the nutrition, dietary and public health issues were much more central to an original assessment of the impact of carbon-based food taxes on the mitigation of the carbon footprint, by acting on the consumption side (García-Muros et al., 2017). Given the high food expenditure rate upon cereals (on average, 22.9%), along with the highest emissions attributable to meat and dairy products, as shown above in this Section, at least in Spain the proposed tax leverage was assessed to trigger a shift of consumption towards cereals, vegetable and fruit and, it was argued, a healthier diet due to reduced intake of calories, proteins, and saturated fats, as well as increased intake of fibers.

However, admittedly, the proposed taxation would be slightly regressive, although that flaw could be eased by adjusting the taxation itself, as well as quantitative economic health benefits associated with improving diets remained unaccounted. Moreover, cereals fell under a unique category without distinction, and further health benefits from possible increased uptake of especially healthy substances were not considered.

Certain old wheat varieties are renowned for the respective nutraceutical properties, mostly due to greater concentration of powerful antioxidant compounds (AOC), mainly flavonoids, as well as of both soluble and insoluble fibers (Di Silvestro et al., 2016; Dinelli et al., 2011; Leoncini et al., 2012; Migliorini et al., 2016). Among those varieties, some of the most interesting are grown in Tuscany, Italy (Ghiselli et al., 2010).

Moreover, a substantial contribution to the nutritional quality of some old wheat varieties derives from the greater concentration of selected minerals fundamental of the human metabolism, among which zinc, which was found to be particularly abundant in few old landraces such as Verna (Migliorini et al., 2016). That mineral was recently indicated as a very important element reducing the risk of some cancer, cardiovascular and diabetic diseases, especially for populations with cereal-rich diets (Zyba et al., 2016).

Based on the widespread use of cereal products in the Mediterranean diet, the transition to healthier raw food ingredients could significantly improve the consumers' health, reducing the associated social and sanitary costs, increasing labor productivity and possibly reducing the sanitary-related environmental burden. So far, to the best knowledge of the authors, possible benefits related to a shifting to healthier diets, as to the components directly concerning the consumers' side, remained unaccounted in life cycle assessment (LCA) studies under both the economic and environmental sides.

About the environmental footprint of typical old wheat varieties, an LCA study of the bread supply chain in Europe revealed critical issues affecting low-input grain farming (Kulak et al., 2015). In particular, while quite obviously low-input farming lowers most parameters of the environmental footprint per *unit of cultivated area*, the same is far from obvious when coming to the impact per *unit quantity* of final product, largely due to the lower yields and consequent larger overall cultivated area, greater fuel and electricity consumption, larger infrastructure on the farming side. The scale issue adds to offset the benefits brought by lower input of fertilizers and pesticides: *e.g.*, the common practice of direct selling small volumes of products to end consumers, or to small shops, produces a far larger fuel consumption per unit product on the distribution and consumers' side.

According to the latter authors, a significant spreading of typical old wheat varieties in Europe could be afforded due to plenty of supplies, with imports rising over domestic production, and declining agricultural land. However, overcoming the respective niche scale, and leading to a relief of the transportation issue, would require a constraint on consumption of the overall products or their composition (Kulak et al., 2015).

Indeed, the economic sustainability of typical old wheat varieties has been limited by lower yields than modern ones, despite their gradual increase (Ghiselli et al., 2010). However, in case of organic or low-input biodynamic crops, the yield gap further reduces, while few typical old wheat varieties grown under low-input farming practices, such as Verna, stand out for the respective nutraceutical properties (Dinelli et al., 2011).

While it would be interesting to check how the yield gap reduces, based on more significant yield metrics, such as the above-mentioned ones (Sonesson et al., 2016), some authors pointed out that the yield of some old landraces, such as emmer and spelt, yielded similar to bread wheat under organic farming, while enjoying a higher protein content (Konvalina et al., 2014). The same authors argued that the same old hulled wheat species would be particularly suitable, showing high nitrogen efficiency expressed as protein yield per unit area, for spring sowing in marginal areas of cereal production, which are prone to winter damage and low productivity, and where organic farming is the norm.

In a study devoted to arbuscular mycorrhizal fungi inoculation for micro-nutrient uptake of durum wheat from the soil, in particular iron and zinc, Ercoli and coauthors found that an increase of wheat protein content occurred only in unfertilized plots, *i.e.* under low nitrogen availability common to organic farming practices (Ercoli et al., 2017). The same authors found as well that, in response to inoculation, the old wheat variety under study ("Senatore Cappelli") undergone a significant enlargement of its root system, potentially improving the respective water and nutrient