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ORIGINAL RESEARCH

Evaluation of the evolution of wheat grain characteristics over the last 166 years using archival samples - A review of the evidence

D.ssa M. Mondini[1]

1 Biologist, Italy

1. ABSTRACT

The analyzed study compared wheat samples preserved between 1850 and 2016, sourced both from the historic Broadbalk agricultural experiment in the United Kingdom and from botanical archives in sixteen countries. The authors observed an increase in non-structural carbohydrates—namely starch and soluble sugars—accompanied by a reduction in the concentration of proteins and numerous minerals in the grain. At Broadbalk, the protein content decreased by 26% between 1850 and 2016. This result is relevant to the passage from "The Choice to Live in Health or Illness" by Dr. A. Colonnese and R. Panzironi, which describes a decrease in the nutritional quality of wheat over time.However, the publication cannot attribute the entire change to a single factor. During the same period, atmospheric carbon dioxide concentrations, temperature, agricultural practices, and cultivated varieties have all changed, including the short-stature varieties selected for high yields. Meta-analysis and independent experiments confirm that high CO2 levels tend to reduce the concentration of protein, zinc, and iron in wheat. Other studies indicate that the result also depends on the variety, nitrogen availability, and soil conditions. The narrative in the book is therefore moderately supported: it documents a real trend, but not a single or inevitable cause for every type of wheat.

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MISSION

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Through articles, reviews, in-depth analyses and expert contributions, the Journal champions evidence-based medicine and science, fostering a correct interpretation of scientific data and countering misinformation. Every piece of content is developed with the aim of translating the complexity of research into understandable, useful and applicable information, while keeping intact the principles of accuracy, transparency and scientific independence.

Free from political, industrial and commercial influence, the journal stands as an authoritative and independent editorial space, dedicated to promoting scientific culture, professional development and the growth of health awareness among the public.

2. ANALYZED STUDY

The research question was whether the nutritional composition of wheat grains has changed over the course of 166 years and whether such changes are associated with environmental and agronomic variations that occurred during the same period. The hypothesis was that the increase in atmospheric carbon dioxide, temperature, and agricultural productivity had favored the accumulation of carbohydrates, proportionally reducing proteins and minerals.The reason for the citation in paragraph 1.2.3 of the book is very specific. "The Choice to Live in Health or Illness" by Dr. A. Colonnese and R. Panzironi refers to this research for the data observed at Broadbalk: a 26% reduction in the protein content of wheat from 1850 to 2016, in a context where short-straw, high-yield varieties have been introduced since the 1960s.The study can document a historical variation in nutrient concentration and show statistical associations with CO2, temperature, yield, and cultivation period. However, it cannot prove on its own that the increase in CO2 or dwarf varieties are the sole cause of the protein and mineral reduction: these factors changed simultaneously and were not separated through a controlled experiment spanning 166 years.

3. MATERIALS AND METHODS OF THE ORIGINAL STUDY

The research analyzed soft and durum wheat grains harvested between 1850 and 2016. A portion came from the Broadbalk Continuous Wheat Experiment at Rothamsted, in the United Kingdom, a field experiment that began in 1843. Another portion came from herbaria and botanical collections from sixteen countries. The samples were intact and showed no visible signs of degradation.For each harvest year, generally three replicates were performed; in the global samples, the number varied from 3 to 18. The authors measured starch, glucose, fructose, sucrose, protein, carbon, nitrogen, and minerals, including iron, zinc, magnesium, manganese, copper, potassium, phosphorus, and calcium. The minerals were quantified using inductively coupled plasma optical emission spectrometry, a technique that measures the chemical elements present in the sample.For Broadbalk, yield data from 1850 to 2016 and the weight of one thousand grains from 1974 to 2016 were also available. The authors primarily compared two periods, 1850-1955 and 1965-2016, and analyzed correlations between wheat composition, CO2, temperature, and precipitation. Since the historical samples came from different locations, years, and varieties, the effect of the genotype was not statistically separated from the effect of the year. The detailed inclusion and exclusion criteria for each sample are not reported in the available material.

4. RESULTS

The most relevant finding for the book concerns protein content. In the Broadbalk samples, total protein content decreased by 26% between 1850 and 2016. The authors found a negative correlation between atmospheric CO2 and protein: as CO2 levels increased, the protein concentration in the grain tended to decrease. Temperature also showed a negative correlation with protein, but in the multifactorial analysis, the statistically significant effect was attributed to CO2 rather than temperature.In the international group, comparing 1850–1955 with 1965–2016, protein concentration dropped from 16.96% to 13.07%, a 23% reduction, with a P-value of 0.049. The P-value indicates the compatibility of the result with the hypothesis that no difference exists: conventionally, values below 0.05 are considered statistically significant. In the same comparison, the carbon-to-nitrogen ratio increased by 20%, consistent with a higher relative proportion of carbon-rich compounds compared to nitrogen-rich ones, such as proteins.Carbohydrates showed an opposite trend. In the global samples, glucose increased significantly, from 1.01 to 1.89 micromoles per gram of dry matter, with a P-value of 0.027. Starch increased by 7%, but this difference between the two periods was not statistically significant. At Broadbalk, starch content reached its highest value in 2016, and wheat yield increased primarily after the 1960s.Regarding minerals, the authors observed a general downward trend with increasing CO2. Negative associations were statistically significant for potassium, magnesium, zinc, iron, and manganese in the global samples. At Broadbalk, mineral concentrations were negatively affected primarily by CO2, with the exception of potassium, which increased over time. These data describe

concentrations in the grain: they do not necessarily indicate that the total amount of nutrients produced per hectare has decreased, because overall yield has grown.

5. INTERPRETATION

In simple terms, the study suggests that wheat produced in recent decades may contain a relatively higher proportion of carbohydrates and a lower proportion of proteins and various minerals. A plausible explanation is the dilution effect: if the grain accumulates more starch and its yield increases, proteins and minerals may represent a smaller percentage of the final weight.However, the mechanism cannot be reduced to dilution alone. Increased CO2 can enhance photosynthesis in C3 plants, the group to which wheat belongs, and reduce the opening of stomata, the small openings on leaves that regulate gas exchange and water loss. Reduced transpiration can alter the transport of nitrogen and minerals from the soil to the plant. Furthermore, the selection of short-straw varieties may have favored higher yields by increasing the number of grains, without each grain becoming richer in proteins or micronutrients.The segment directly documented by the publication subject to the Evidence Review is therefore: in the wheat archived at Broadbalk, during the period when CO2 and yields increased and semi-dwarf varieties were introduced, protein concentration decreased by 26% and several mineral concentrations declined. The causal interpretation attributing this phenomenon to a combination of CO2, yield, and genetic improvement is reasonable, but remains partial because the study is observational and does not fully isolate the factors.

6. INDEPENDENT CONFIRMING EVIDENCE

A meta-analysis specifically on wheat gathered experiments conducted under realistic field conditions, excluding greenhouses and closed growth chambers. It found that increased CO2 reduced the nitrogen concentration in the grain by an average of 8.4%, a measure closely linked to protein. Since yield increased at the same time, as did the total nitrogen content per cultivated area, the result confirms that nutritional concentration and total production are two different aspects. The same meta-analysis observed reductions in many minerals, including iron, zinc, magnesium, and manganese, and concluded that dilution due to higher yield alone does not explain the entire variation [1].Multicenter research in FACE systems—that is, open-field crops enriched with CO2 without enclosing the plants in a chamber—has confirmed the direction of the effect in wheat. Compared to ambient CO2, elevated CO2 was associated with a 6.3% reduction in protein, 9.3% in zinc, and 5.1% in iron in the grain. This study primarily reinforces the narrative that higher CO2 can reduce the density of certain nutrients in wheat, although it does not reconstruct the entire agricultural history since 1850 [2].An independent comparison between 63 historical and modern spring wheat cultivars showed that, as yields increased over time, the concentrations of all evaluated minerals except calcium decreased. The result was particularly evident in the commercial soft white wheat group; in hard red wheat, however, mineral concentrations remained substantially constant. This difference is important because it confirms that varietal selection can contribute to the mineral quality of the grain, but it also shows that the decline is not the same in every genetic group [3].Overall, independent evidence supports two parts of the book's statement: increased CO2 can be associated with a reduction in protein and mineral concentration; varietal selection and increased yield can further modify mineral content. The evidence is stronger for the average direction of the CO2 effect and less strong for quantifying how much short-straw varieties weighed in the specific Broadbalk experiment.

7. CONFLICTING EVIDENCE

A two-year FACE experiment, conducted with two CO2 levels and three nitrogen fertilization levels, found a more limited effect compared to that observed in other research. Elevated CO2 slightly reduced albumin/globulin and total gluten, but did not change iron, zinc, and sulfur concentrations or bread volume. Nitrogen and the year of cultivation had more marked effects than CO2 on many wheat quality characteristics [4].This result does not invalidate the association observed in the original study. Instead, it indicates that the wheat's response depends on the experimental context, the cultivar, the availability of nutrients in the soil, and the extent of the increase in production. In particular, it is incorrect to state that

higher CO_2 necessarily reduces all minerals in every variety and in every environment. Conflicting evidence makes it more prudent to attribute protein and mineral reduction exclusively to short-straw varieties or exclusively to CO_2.

8. QUADRO COMPARATIVO E SINTESI DELLE EVIDENZE

The table distinguishes the historical data observed in the original study from independent evidence that confirms or delimits the narrative of the book's paragraph.

Quadro comparativo

Reference	Study type	Population or model	Main result	Direction of evidence	Strength of evidence
Original study	Historical observational with archival samples	Wheat 1850-2016; Broadbalk and samples from 16 countries	At Broadbalk, protein reduced by 26%; decrease in numerous minerals and relative increase in carbohydrates.	direct confirmation	moderate
[1]	Meta-analysis	Field wheat experiments, FACE and open-top chamber	Elevated CO2 associated with an average 8.4% reduction in grain nitrogen and decreases in several minerals.	direct confirmation	high
[2]	Multicenter FACE experiments and meta-analysis	C3 crops, including wheat, grown in open fields	In wheat: protein reduced by 6.3%, zinc by 9.3%, and iron by 5.1% with elevated CO2.	direct confirmation	high
[3]	Comparative observational	63 historical and modern spring wheat cultivars	With higher yields, a decrease in almost all minerals; different response between commercial classes.	indirect confirmation	moderate
[4]	FACE experiment	Wheat, two years, ambient or elevated CO2 and three nitrogen levels	Slight reduction in some proteins, but iron, zinc, and sulfur unchanged.	conflicting evidence	moderate

9. SINTESI EDITORIALE E CONCLUSIONI

CONCLUSIONS

The study analyzed documents a reduction in the protein content of wheat at Broadbalk between 1850 and 2016, accompanied by a decrease in several minerals and a relative increase in carbohydrates. This shift is well-supported as a historical observation. Independent evidence confirms that elevated CO2 can reduce the concentration of protein, zinc, iron, and other minerals in wheat.The section regarding short-straw varieties requires greater caution. It is biologically and agronomically plausible that selection for high yields contributes to the dilution of certain nutrients, but its weight relative to CO2, temperature, nitrogen, soil, and cultivar cannot be precisely defined by the original study. The narrative is therefore moderately supported and does not justify absolute conclusions regarding the composition of all modern cereals.

Aggiornato al 17/11/2026. Questo contenuto riflette una sintesi divulgativa delle evidenze scientifiche al momento della pubblicazione e non sostituisce il parere medico.

10. TRANSPARENCY AND SCIENTIFIC RESPONSIBILITY

Artificial Intelligence was used solely as a tool for editorial and documentary support. All content, interpretations, bibliographic citations and conclusions have been verified, reviewed and approved by the author, who assumes full scientific responsibility for them.

The manuscript was also subjected to independent peer review prior to publication.

To ensure the greatest transparency, the complete history of the article, including the dates of submission, revision, acceptance and publication, as well as information on the peer review process, is available on the dedicated Article History page.

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