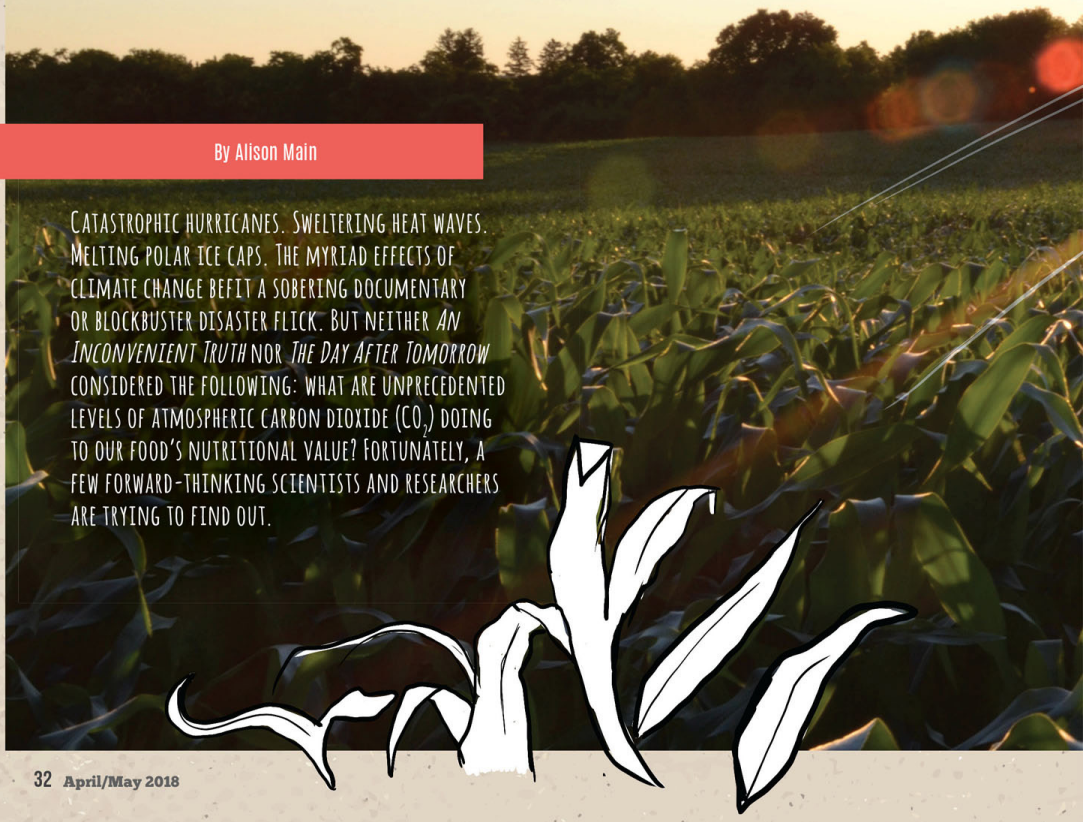
Are We Carb(on)-loading Our Crops?

How climate change is altering our food's nutritional value

By Alison Main

Catastrophic hurricanes. Sweltering heat waves. Melting polar ice caps. The myriad effects of climate change befit a sobering documentary or blockbuster disaster flick. But neither *An Inconvenient Truth* nor *The Day After Tomorrow* considered the following: what are unprecedented levels of atmospheric carbon dioxide (CO_2) doing to our food's nutritional value? Fortunately, a few forward-thinking scientists and researchers are trying to find out.



"Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time."

– Intergovernmental Panel on Climate Change

(Don't) Pour Some Sugar on Me

"You are what you eat." If that old adage is true, then we're about to become a lot less nutritious, no matter how many green goddess smoothies we toss back.

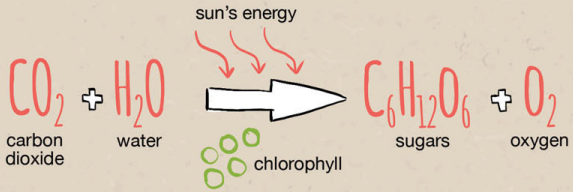
Recent research into plant physiology and agricultural biology indicates our skyrocketing levels of atmospheric CO_2 are changing the chemical composition of plant leaves, stems, roots, fruits, and tubers. How exactly? Increased CO_2 kickstarts a rush of photosynthesis, making plants grow faster, which seems like a positive thing at first.

Augmented plant growth may not be helpful, however, when the food crops we're yielding are laden with complex sugars. This additional growth results in a higher carbohydrate content at the expense of other vital nutrients (e.g., iron, zinc, and protein) and ultimately may be detrimental to our nutrition and health.[1]

Photosynthesis is the plant-based food-making cycle fundamental to sustaining all life on earth. To make food, plants need carbon dioxide (CO_2), water (H_2O), and sunlight. Humans and animals breathe out CO_2, which plants subsequently take in through small pores (stomata) in their leaves. Water is absorbed through plant roots and passed through vessels in the stem to the leaves, where the process of photosynthesis occurs.

Now flash back to your old crayon pictograms. You may remember that leaves are made up of very small cells, which contain tiny organelles called chloroplasts. Each chloroplast contains a green chemical known as chlorophyll, which absorbs the sun's energy to create a chemical reaction. This is where CO_2 and H_2O are separated into their individual molecules and combined into new products. Oxygen (O_2) is released from the plant into the air (which humans and animals breathe). And a sugar is created, $C_6H_{12}O_6$, or glucose, that is used by the plant for energy.

What happens to this cycle when there's an overabundance of atmospheric CO_2? When plants receive more CO_2 and water than they need to sustain their own lives, they produce extra food (the $C_6H_{12}O_6$ sugar). This surplus is stored in the plant parts and fruits that humans and animals eat for nourishment. The short-hand is: we wind up with sugar-heavy fruits and vegetables. This is not good for our food's nutritional profile.



The Heat Is On

There's a difference between global warming and climate change. *Global warming* refers to the upward trend in surface temperatures across the entire Earth since the early 20th century, attributed to human causes, specifically the increase in fossil fuel emissions since the Industrial Revolution. Since 1880, the average worldwide surface temperature has increased by about 1.4°F (0.8°C).[2] *Climate change* refers to a broad range of global phenomena, including sea level rises; ice mass loss in Greenland, Antarctica, the Arctic, and mountain glaciers; shifts in flower/plant blooming; and extreme weather events.[2]

The Intergovernmental Panel on Climate Change is a group of 1,300 independent scientific experts gathered from countries all over the world under the auspices of the United Nations. In its Fifth Assessment Report, the panel concluded that "there's a more than 95 percent probability that human activities over the past 50 years have warmed our planet."[3]

Carbon dioxide is one of the "greenhouse" chemicals whose increasing concentration in our atmosphere contributes to global warming by reflecting warmth back to the surface of our planet. And its concentration continues to grow. In a report from the National Oceanic and Atmospheric Administration, CO_2 levels measured at NOAA's Mauna Loa Baseline Atmospheric Observatory rose by 3 parts per million (ppm) to 405.1 ppm in 2016. And by February 2017, CO_2 levels at Mauna Loa had already climbed to 406.42 ppm.[4]

This two-year, 4-ppm surge is unprecedented in the observatory's 59-year record. The NOAA report quotes Pieter Tans, lead scientist of the NOAA Global Greenhouse Gas Reference Network, explaining, "The rate of CO_2 growth over the last decade is 100 to 200 times faster than what the Earth experienced during the transition from the last Ice Age…This is a real shock to the atmosphere."[4]

Why is this happening? The industrial activities that our modern civilization depends upon have raised atmospheric CO_2 levels from 280 ppm to an astonishing 400 ppm in the last 150 years. In fact, atmospheric concentrations of carbon dioxide, methane (CH_4), and nitrous oxide (N_2O), the three greenhouse gases primarily responsible for human-induced climate change, are at concentrations unprecedented in at least the last 800,000 years.[3]

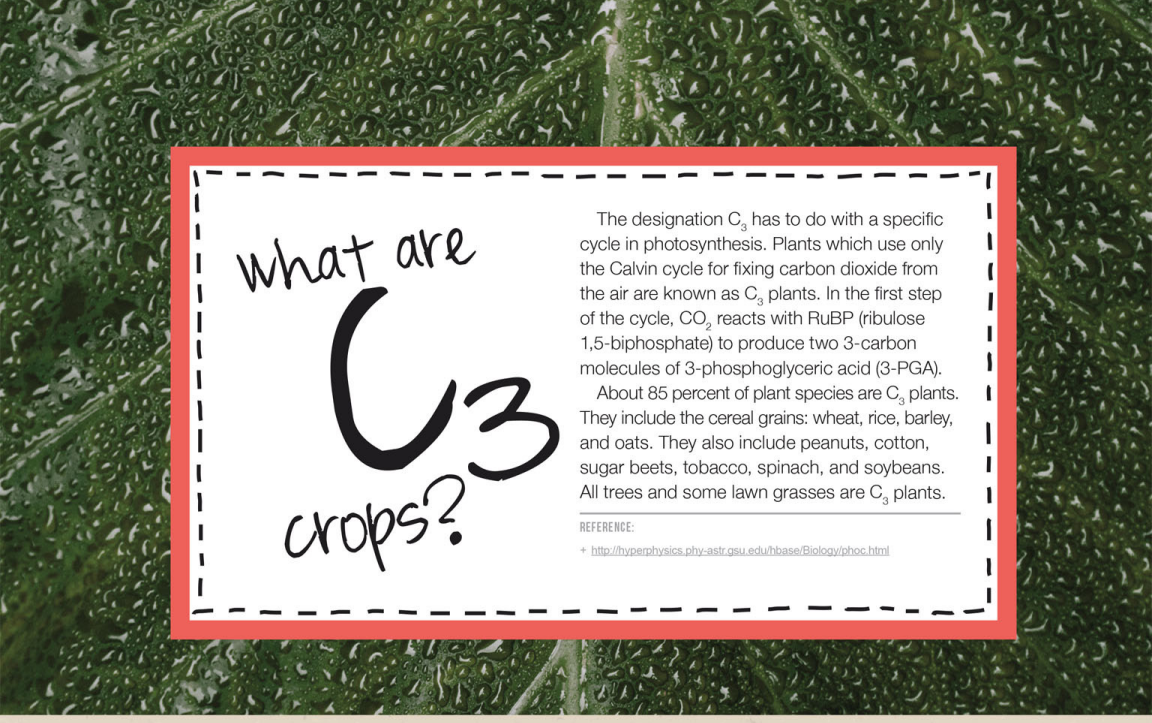
That's a lot more CO_2 for our plants to process. And maybe it is *too much* for the health of our food supply.

> "Human influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history. Recent climate changes have had widespread impacts on human and natural systems."
> -Intergovernmental Panel on Climate Change

Blades of Grass

A 2014 research study by Irakli Loladze of the Catholic University of Daegu systematically collected and evaluated existing information on the effects of elevated levels of CO_2 on plant tissues, notably the effects on minerals and trace elements that are important for human health, such as calcium, zinc, and iron. His dataset encompassed 7,761 observations made over the last 30 years, covering 130 different plant species and crop varieties.[1] And his conclusions are a cause for concern.

Elevated CO_2 levels were found to reduce in plants the overall concentration of 25 important minerals—including calcium, potassium, zinc, and iron—by 8 percent on average. Furthermore, Loladze found that an increased exposure to CO_2 also increased the ratio of carbohydrates to minerals in these plants.[1]



what are C_3 crops?

The designation C_3 has to do with a specific cycle in photosynthesis. Plants which use only the Calvin cycle for fixing carbon dioxide from the air are known as C_3 plants. In the first step of the cycle, CO_2 reacts with RuBP (ribulose 1,5-biphosphate) to produce two 3-carbon molecules of 3-phosphoglyceric acid (3-PGA).

About 85 percent of plant species are C_3 plants. They include the cereal grains: wheat, rice, barley, and oats. They also include peanuts, cotton, sugar beets, tobacco, spinach, and soybeans. All trees and some lawn grasses are C_3 plants.

REFERENCE:

+ http://hyperphysics.phy-astr.gsu.edu/hbase/Biology/phoc.html

> "one cannot think well, love well, sleep well, if one has not dined well."
> - Virginia Woolf

Overall, the increase in CO_2 in the atmosphere that has happened since the Industrial Revolution is thought to have raised the production of sugars and other carbohydrates in plants by up to 46 percent.[1] And since CO_2 levels are expected to rise even further in the coming decades, this is not a good trend.

In a 2017 *Politico* article, Loladze is quoted as saying, "Every leaf and every grass blade on earth makes more and more sugars as CO_2 levels keep rising…We are witnessing the greatest injection of carbohydrates into the biosphere in human history—[an] injection that dilutes other nutrients in our food supply."[6]

There is, of course, the counter-argument—that rising CO_2 levels could be a boon to our agricultural economy. The logic rests in the following paradigm: More CO_2 in our atmosphere aids photosynthesis, which thus augments plant growth, ultimately yielding increased volume of food production. This so-called "carbon enrichment" helps produce more resilient food crops (e.g., maize, soybeans, wheat, and rice) with reduced water needs as it lengthens growing seasons in colder regions of the farm belt. Beyond food production, another benefit cited is more lush vegetation, with satellite imagery showing a 25 to 50 percent greening in the world's vegetated areas. Increased vegetation helps to control water runoff and provides additional habitats for animal species.[7]

The problem with this argument is that it does not account for the net-sum negative effects of climate change. Not to mention that, as new research shows, when it comes to an enhanced, rapidly growing food supply, quantity does not always equal quality.

Starving for Nutrition

A seminal 2014 paper published in *Nature* highlighted the connection between elevated atmospheric CO_2 levels and lower concentrations of zinc and iron in C_3 grains and legumes (see box). Most of the estimated two billion people suffering from dietary deficiencies of zinc and iron rely on C_3 grains and legumes as their primary source of nutrients.[8] The authors called this out as a new challenge for global health, since a rapidly declining nutritional profile of our C_3 crops may further aggravate this nutritional deficit.

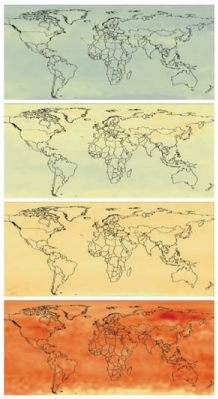
Loladze's research furthers this point. This reduction in the nutritional value of plants could have profound impacts on human health, causing malnutrition

> "knowledge is the food of the soul."
> -Plato

A Picture Worth a Thousand Words

NASA has created a time-lapse series that shows global changes in the concentration and distribution of carbon dioxide since 2002 at an altitude range of 1.9 to 8 miles. The yellow-to-red regions indicate higher concentrations of CO_2, while blue-to-green areas indicate lower concentrations, measured in parts per million (ppm).

+ Data source: Atmospheric Infrared Sounder (AIRS).
+ Credit: NASA
+ https://climate.nasa.gov/interactives/climate-time-machine



even if a person consumes enough calories. Diets that are poor in minerals (in particular, zinc and iron) can lead to reduced growth in childhood, to a reduced ability to fight off infections, and to higher rates of maternal and child deaths. This type of malnutrition is common around the world because many people eat primarily a limited number of staple crops, and do not eat enough foods that are rich in minerals, such as fruits, vegetables, dairy, and meats. Loladze argues that these dietary changes might contribute to the rise in obesity, as people eat increasingly starchy plant-based foods, and eat more to compensate for the lower mineral levels found in crops.[1]

Another nutritional concern is protein deficiency. A 2017 paper in *Environmental Health Perspectives* delved into the global and regional risks of protein deficiency due to rising CO_2 emissions. The authors concluded that crops grown under elevated CO_2 concentrations contain less protein, most particularly in rice and wheat, which are primary sources of dietary protein in many countries. Their data showed that rice, wheat, barley, and potato protein contents decreased by 7.6 percent, 7.8 percent, 14.1 percent, and 6.4 percent, respectively. Consequently, 18 countries (including India, Bangladesh, Turkey, Egypt, Iran, and Iraq) may lose more than 5 percent of their dietary protein. Greater than 7-percent decreases in protein intake are predicted for plant-based diets under elevated CO_2, with countries dependent on C_3 staples particularly affected, including Central Asia, North Africa and the Middle East, Central and Eastern Europe, and China.[9]

Assuming today's diets and comparable levels of income inequality stay constant, the research team estimated that by the year 2050, with predicted atmospheric CO_2 concentrations greater than 500 ppm, an additional 1.6 percent of the world's population (148.4 million people) may be placed at risk of protein deficiency.[9]

Too Many Spoons Full of Sugar

Nutrigenomics integrates genomic science with nutrition and other lifestyle factors. This emerging science recognizes the importance of nutrition in modulating an individual's gene expression. This is a key consideration in the rise of chronic disease. According to several studies on the topic, "all diseases can be reduced to imbalances in four overarching processes: inflammatory, metabolic, oxidative, and psychological stress. Diseases arise because of genetic predispositions to one or more of these stressors. Nutrigenomics represents a major effort to improve our understanding of the role of nutrition and genomic interactions in at least the first three of these areas."[5]

> "Let food be thy medicine and medicine be thy food."
> -Hippocrates

Ancestral and aboriginal populations did not suffer our modern afflictions of obesity, diabetes, and cardiovascular disease. Deemed "diseases of civilization," these maladies emerged when populations adopted a high-sugar, high-fat "Western diet" for the first time, and they have been on a dramatic rise since.[5]

Using food as medicine is a concept as old as Hippocrates, the idea being that the foods we eat determine whether or not we become ill or heal from disease. Keto or Paleo, vegan or carnivore, we need a careful balance of nutritious foods that include antioxidants, phytonutrients, vitamins, minerals, fatty acids, fiber, and more to keep our bodies in homeostasis. Proper nutritional balance helps decrease inflammation, balance hormones, alkalize the body, manage blood sugar, detoxify, and enhance nutrient absorption. Anyone who has ever holed up in their college dorm with packages of ramen noodles, sugar cereals, and neon-colored gummy worms knows full well that such a junk food recipe does not support a healthy body.

The Balance of Nature

In his book *In Defense of Food: An Eater's Manifesto*, Michael Pollan puts forth a defining maxim to get human health and nutrition back on track. After decades of succumbing to an industrially driven Western diet, he suggests that we "Eat food. Not too much. Mostly plants." But what happens to Pollan's driving philosophy in the face of a sugar-loaded plant kingdom?

There is a delicate balance between all livings things on this earth. A shift in one will shift another. And whether or not we want to admit it, our world's atmosphere is changing. We neither live nor eat in a vacuum. With alterations in crop quality increasingly affecting human health and nutrition, malnourished Arctic polar bears may no longer be the number one symbol of climate change in the years ahead.

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