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Brief Report

Innovative Agrochemical Models of Photosynthesis Driven by Foliar Nutrient Applications

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Abstract

Plants produce glucose through a well-defined agrochemical process that uses carbon dioxide and water as inputs. This reaction occurs autonomously in the leaves, powered by solar energy and catalyzed by the chlorophyll pigment. Recent advancements in foliar nutrition have introduced groundbreaking changes to this mechanism by directly influencing its core biochemical pathways. The aim of this study was to refine theoretical models describing the balance between photosynthesis and respiration. A comprehensive eco-physiological experiment was conducted at the University of Debrecen between 2020 and 2024, using organic foliar solutions including aspirin protect, baking soda, and *Saccharomyces cerevisiae* dry yeast, along with trace compounds such as Epsom salt and hydrogen peroxide, to enhance the plant's photosynthetic biochemistry. These interventions were evaluated through conceptual modeling and validated using high-precision digital sensors. The findings demonstrated that the conventional photosynthesis equation can be modified by introducing specific ions and nutrients directly into plant tissues. Dry yeast served as a potassium source for cellular uptake, while aspirin dissolved in deionized water facilitated calcium ion absorption through the foliage. Additionally, baking soda was found to stimulate leaf development by contributing nitrate ions. Based on these foliar nutrition trials, the classical photosynthesis equation can be revisited and potentially revised, paving the way for future updates to plant biochemical models. The results indicate that photosynthetic efficiency is modulated by nutrient availability, particularly under foliar and root-applied nutrient regimes involving specific applications of nitrate, potassium, and calcium. Continued experimentation with diverse foliar formulations, sensor technologies, and targeted physiological parameters is recommended to further optimize photosynthetic efficiency in plants.

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1. Introduction

Photosynthesis is a fundamental biochemical process that takes place in plant cells. It also occurs in algae and certain types of bacteria. The general reaction involves six molecules of carbon dioxide combining with six molecules of water, driven by solar radiation in the 380–780 nm wavelength range, and absorbed by chlorophyll pigments (types a and b, with formulas $C_{55}H_{72}MgN_4O_5$ and $C_{55}H_{70}MgN_4O_6$, respectively). This process produces glucose ($C_6H_{12}O_6$) and releases six molecules of oxygen as a byproduct. Photosynthesis is essential, as it provides the organic compounds that sustain plant life and supplies atmospheric oxygen necessary for the survival of most living organisms. Conversely, cellular respiration in plants occurs when glucose is metabolized in the presence of six molecules of oxygen, generating adenosine triphosphate (ATP) and releasing heat. This process effectively reverses photosynthesis, resulting in the formation of six molecules of carbon dioxide and six molecules of water (Equation 1). The fundamental equation for photosynthesis was first published

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in 1893 by American plant scientists Charles Reid Barnes and Conway MacMillan, both of whom specialized in plant eco-physiology.

Sunlight and chlorophyll a+b (photosynthesis)

$6CO_2 + 6H_2O$ $C_6H_{12}O_6 + 6O_2$ (1)

ATP and heat (respiration)

The key inputs for this reaction are carbon dioxide from the atmosphere and water absorbed from the soil through plant roots. The overall equation simplifies the outputs to sugar - commonly represented by the empirical formula CH_2O—and oxygen gas (O_2), which is released into the air. This basic model is widely used in leading academic plant biology textbooks as a concise explanation of this essential biochemical process. The concept of a reversible equilibrium between photosynthesis and cellular respiration in plants has been previously described [1]. A similar representation appears in other widely used academic references, including the most recent edition of *Introduction to Plant Physiology* [2]. Modern eco-physiology texts also continue to present this classic photosynthesis model in its fundamental form. For instance, *Teaming with Nutrients* includes the same formula [3], and the companion reference *Teaming with Microbes* offers a comparable depiction of plant photosynthesis. Interestingly, recent literature has also noted that certain soil microbes - specifically protozoa such as flagellates - exhibit autotrophic behavior and are capable of photosynthesis as well [4].

The production of glucose in the classical photosynthesis equation is a logical outcome, representing a simple rearrangement of carbon dioxide and water atoms into a carbon–hydrogen–oxygen (C–H–O) structure - specifically, $C_6H_{12}O_6$. Carbon, hydrogen, and oxygen are the fundamental elements that form the backbone of organic molecules. Glucose is one of the most essential carbohydrate compounds synthesized by plants and also by honeybees [5]. The traditional photosynthesis model, however, conceals the complex biochemical and photo physical mechanisms by which light energy within the 380–780 nm spectrums drives the conversion of these basic elements into an organic molecule like simple sugar. As a result, the conventional expression of photosynthesis often serves more as a simplified, linguistic description of a botanical biochemical reaction rather than a comprehensive scientific definition that captures its full mechanistic and applied complexity.

As a result, agrobiologists and agro-chemists began to explore how complex nutrient interactions - whether present in the soil solution or applied via foliar feeding - affect this critical biological process. Mulder's chart, which illustrates the synergistic and antagonistic relationships between soil nutrients and their influence on plant uptake, has previously been referenced [6]. For optimal growth and development, plants require a range of macronutrients, including nitrogen, potassium, calcium, phosphorus, and magnesium, in addition to the basic elements carbon, hydrogen, and oxygen [3]. Nitrogen is especially crucial for the synthesis of chlorophyll *a* and the formation of nucleotides - the building blocks of DNA and RNA. On average, nitrogen constitutes about 4% of a plant's dry mass, underscoring its significance in promoting healthy vegetative growth. Since atmospheric nitrogen (N_2) cannot be directly assimilated by plants, it must first be converted into bioavailable forms such as nitrate (NO_3^-) [3].

Potassium often referred to as potash, plays a vital role in plant physiology by regulating enzymatic activity and supporting starch synthesis - starch being the primary storage form of glucose produced through photosynthesis. Potassium also influences water transport and stomata function, both of which are essential for maintaining photosynthetic efficiency and turgor pressure [3]. This explains why potassium is essential for robust plant nutrition and contributes significantly to flowering and fruit development. Similarly, calcium functions as a structural component of cell walls and is involved in activating plant enzymes and facilitating cell division [3].

Taken together, these insights reveal that the conventional model of photosynthesis cannot be fully understood in isolation from the broader context of plant nutrition and physiological development. Scientists have explored advanced models of photosynthesis from various perspectives. In the research article *Recent Advances in Understanding and Improving Photosynthesis* [7], the authors concluded that enhancing photosynthetic water use efficiency (WUE) could significantly boost crop productivity. Similarly, in another study titled *Perspectives on Improving Photosynthesis to Increase Crop Yield* [8], the authors emphasized that photosynthetic efficiency can be maximized through a comprehensive approach, improving plant resilience against environmental fluctuations and stresses. This would ultimately support sustainable crop yields under diverse abiotic and biotic stress conditions. The latter research particularly highlighted the importance of improving both water use efficiency (WUE) and nitrogen use efficiency (NUE) under abiotic stress to optimize photosynthetic performance in plants. In conclusion, both of these pioneering studies underscore the positive role that water and nutrient management play in enhancing photosynthesis. These benefits can be achieved through foliar nutrition techniques, as demonstrated by the research conducted at Debrecen University [9].

The theoretical framework presents an improved photosynthesis model that incorporates nutrient supplementation as a crucial factor in optimizing carbon fixation and oxygen release. The updated general equation for photosynthesis is illustrated in (Equation 2).

Sunlight and chlorophyll a+b

$$6CO_2 + 6H_2O + \text{Nutrients}\ C_6H_{12}O_6 + 6O_2 \quad (2)$$

[NO_3^- , K^+, Ca^{2+} among others]

This article proposes that the photosynthesis equation can be refined and enhanced through the incorporation of foliar and root treatment compositions. The research presents updated models of photosynthesis equations based on natural foliar and root treatments, including aspirin (acetylsalicylic acid), dry yeast, baking soda, Epsom salt, and hydrogen peroxide.

2. Materials and Methods

Deionized water was used as the solvent for all solution preparations, following the standard protocol established during the doctoral research (2020–2024) [9]. The nutritional treatments were formulated from a variety of commercially available materials: aspirin protect (100 mg. L^{-1}) from Bayer (Germany), baking soda at 0.5% from SZILASFOOD KFT (Hungary), Epsom salt at 0.5% from K.H.A Pharma (Jordan), and hydrogen peroxide at 1% sourced from BORBIRO Patika (Hungary). Instant dry yeast (*Saccharomyces cerevisiae*) at 0.5% was obtained from ASTRICO Yeast Industries (Egypt) [9].

2.1. Sample Collection

Four replicates were collected for each solution type, with sample volumes ranging between 1–2 mL. Three separate, pre-calibrated Horiba Laqua Twin smart probes (Advanced Techno Company, Kyoto, Japan) were used to measure the concentrations of nitrate (NO_3^-), potassium (K^+), and calcium (Ca^{2+}), all reported in mg. L^{-1}.

2.2. Analytical Methods

Raw data were expressed as ranges (minimum and maximum values) and recorded in Microsoft Excel. Mean values were statistically compared using the Tukey test in Minitab 21, with significance determined at the 5% level.

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3. Results

Table 1 presents the chemical composition of the tested nutrient solutions. Deionized water (H_2O) exhibited the lowest nitrate concentration, ranging from 7 to 11 mg. L^{-1}. In contrast, Epsom salt (magnesium sulfate heptahydrate, $MgSO_4 \cdot 7H_2O$) showed the highest nitrate content among the standard solutions, with levels between 17 and 18 mg. L^{-1}. Hydrogen peroxide (H_2O_2) contained a moderate nitrate concentration, ranging from 10 to 14 mg. L^{-1}. Compared to all other solutions, baking soda (0.5% sodium bicarbonate, $NaHCO_3$) displayed a significantly higher nitrate concentration, measured at 51–55 mg. L^{-1}, although nitrates are considered a minor constituent in this solution. As shown in (Table 1), vegetative growth and chlorophyll content are influenced by both the concentration and availability of nitrates.

With regard to potassium (K^+), the instant dry yeast solution containing Saccharomyces cerevisiae (0.5%) emerged as the sole significant source, exhibiting a potassium concentration between 36 and 38 mg. L^{-1}. Potassium plays a crucial role during the flowering stage of plant development (Table 1).

In terms of calcium (Ca^{2+}), the aspirin solution (100 mg. L^{-1} acetylsalicylic acid, $C_9H_8O_4$) recorded the highest concentration, ranging from 48 to 56 mg. L^{-1} - a significant difference compared to the other solutions. Epsom salt ($MgSO_4 \cdot 7H_2O$) contained a relatively low calcium level (5–10 mg. L^{-1}), while deionized water held a slightly higher concentration (10–11 mg. L^{-1}). Calcium is essential for plant growth, particularly during the fruiting stage, and is generally important for leaf vitality and stem structural integrity (Table 1).

Table 1. Chemical analysis of plant solutions in the experimental study.

Source	Active Ingredient (Concentration)	Smart Sensor Minor Ingredients Detections	Range (mg. L^{-1}) (Min-Max)
Baking soda	$NaHCO_3$ (0.5%)	NO_3^-	(51-55)*
Instant dry yeast	*Saccharomyces cerevisiae* (0.5%)	K^+	(36-38)*
Aspirin	$C_9H_8O_4$ (100 mg. L^{-1})	Ca^{2+}	(48-56)*
Deionized water	H_2O (Pure)	NO_3^- K^+ Ca^{2+}	(7-11) (0-0) (10-11)
Epsomite salt	$MgSO_4.7H_2O$ (0.5%)	NO_3^- K^+ Ca^{2+}	(17-18) (0-0) (5-10)
Hydrogen peroxide	H_2O_2 (1%)	NO_3^- K^+ Ca^{2+}	(10-14) (0-0) (0-0)

* Significant means (*P*-Value < 0.05).

4. Discussion

Based on both theoretical and experimental evaluations, this study helped researchers revise the conventional photosynthesis formula under various foliar and root nutrient treatments.

When baking soda dissolves in water, it undergoes hydrolysis to form unstable carbonic acid (H_2CO_3) and sodium hydroxide (NaOH). The carbonic acid then breaks down into carbon dioxide and water, as shown in (Equation 3). Additionally, under anaerobic conditions and in the presence of glucose, the yeast *Saccharomyces cerevisiae* produces carbon dioxide, ethanol (C_5H_5OH), and heat, as illustrated in (Equation 4). Lastly, aspirin contains acetylsalicylic acid ($C_9H_8O_4$), which hydrolyzes in water to yield salicylic acid ($C_7H_6O_3$) and acetic acid (CH_3COOH), as shown in (Equation 5).

$$NaHCO_3 + H_2O \; CO_2 + H_2O + NaOH \quad (3) \longrightarrow$$

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$$C_6H_{12}O_6 \rightarrow C_5H_5OH + CO_2 + ATP \quad (4)$$

$$C_9H_8O_4 + H_2O \rightarrow C_7H_6O_3 + CH_3COOH \quad (5)$$

Baking soda - also known as sodium hydrogen carbonate or sodium bicarbonate - at a 0.5% concentration is mildly basic, with a pH of around 7.6 due to the formation of sodium hydroxide. When dissolved in deionized water, which typically contains 7–11 mg. L^{-1} of nitrates, it yields a nitrate-rich solution containing 51–55 mg. L^{-1} of NO_3^- and no detectable calcium, as shown in (Table 1). This nitrate enrichment is linked to the presence of protein-based additives in the baking soda, composed of amino acids, whose basic structure includes nitrogen atoms [9]. The protein in sodium bicarbonate originates from mustard seeds (containing 25–30% protein by weight) and celery seeds (18–25% protein by weight). Fungi generally thrive in highly acidic media, where hydrogen ions are abundant and often associated with toxic compounds like ammonium (NH_4^+). Since baking soda is a food-grade substance, it makes sense that it contains nitrates, which are more stable in slightly alkaline environments - conditions that are typically unfavorable for fungal growth but beneficial for plant health. Additionally, nitrate levels have shown a positive correlation with chlorophyll content, as measured by the SPAD index [9]. Therefore, foliar application of baking soda could play a role in modifying the photosynthesis formula, as illustrated in (Figure 1).

Because *Saccharomyces cerevisiae* requires glucose for aerobic respiration to produce carbon dioxide - and also carries out anaerobic respiration using glucose to generate both carbon dioxide and ethanol (C_5H_5OH) - yeast can be considered an indirect nutrient source that may enhance photosynthetic efficiency. Notably, yeast releases potassium in the range of 36–38 mg. L^{-1} (Table 1), a macronutrient that is strongly recommended for root application in plants [9]. However, since *S. cerevisiae* consumes glucose during fermentation, there's a risk it could deplete the glucose synthesized through photosynthesis. To avoid this and still benefit from its outputs, adding yeast to the soil allows plants to absorb carbon dioxide (or a combination of carbon dioxide and ethanol) along with potassium. Potassium is a mobile nutrient, capable of moving from the roots to the leaves through plant sap. Additionally, a 0.5% dry yeast solution has a pH of 6, making it suitable for use in root nutrition. Ethanol also contains carbon, hydrogen, and oxygen - the key elements needed to generate carbon dioxide and water, both essential to the photosynthetic process.

Aspirin protect is an enteric - coated tablet containing maize starch—composed of amylose and amylopectin polysaccharides - that is also a good source of calcium [9]. This coating prevents it from dissolving in the acidic environment of the stomach, allowing it to break down instead in the more alkaline conditions of the small intestine, where a larger surface area supports better absorption. A 50 mg. L^{-1} solution of aspirin releases about 16.5 mg. L^{-1} of calcium ions, while a 100 mg. L^{-1} solution yields between 48 and 56 mg. L^{-1}, as shown in (Table 1). Calcium is essential for the formation of pectin polysaccharides in plant cell walls [9]. Therefore, foliar feeding with hydrolyzed aspirin could directly contribute to the observed changes in the photosynthesis formula, as depicted in (Figure 1).

In conclusion, aspirin (100 mg. L^{-1}) and baking soda (0.5%) serve as more effective sources of carbon, hydrogen, and oxygen compared to yeast. Both contribute to the generation of carbon dioxide and water due to their atomic composition (C-H-O) and their ability to deliver nutrients directly to plant leaves - immobile calcium cations from aspirin and nitrates from baking soda. These properties allow them to more efficiently support the photosynthesis process, particularly through the advantages offered by foliar nutrition, which outperforms the 0.5% yeast solution in terms of speed and nutrient accessibility.

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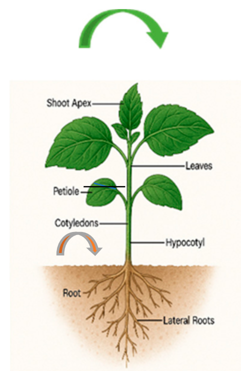

Figure 1. Plant nutrition using natural products via leaves or roots (typical model seedling is any vegetable during and after true leaves stage).

5. Conclusions

Aspirin (100 mg. L^{-1}) and baking soda (0.5%) both contain carbon, hydrogen, and oxygen atoms, making them effective natural sources for supplying essential elements to plant leaves. Aspirin can also provide calcium-an immobile cation-while baking soda contributes nitrates directly to the foliage. These characteristics make both substances more effective inputs for driving photosynthesis and glucose production compared to yeast solution (0.5%). Due to its rapid foliar absorption and innovative delivery, acetylsalicylic acid (aspirin) enables quicker nutrient uptake by photosynthetic tissues than yeast. Baking soda also acts as a supplemental provider of carbon, hydrogen, and oxygen, and it supports foliar uptake of carbon dioxide, water, and nitrates. As such, aspirin and baking soda can be regarded as superior natural foliar fertilizers across various plants developmental stages, including vegetative growth, stem elongation, flowering, and fruiting. On the other hand, yeast solution (0.5%) serves as an indirect source of carbon dioxide, water, and potassium-primarily enhancing photosynthesis through root uptake. Therefore, the revised photosynthesis model presented in (Equation 2) offers a more comprehensive and detailed framework, incorporating specific roles of nitrate, potassium, and calcium, compared to the earlier version outlined in (Equation 1).

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Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
MOHE	Ministry of Higher Education
JAEA	Jordanian Agricultural Engineers Association

References

1. Urry, L.; Cai;n, M.; Wasserman, S.; Minorsky, P.; Reece, J. *Campbell Biology*, 11th ed.; Pearson: Boston, USA, 2016.
2. Hopkins, W.; Hüner, N. *Introduction to Plant Physiology*, 4th ed.; John Wiley & Sons Inc, USA, 2008.
3. Lowenfels, J. Teaming with Nutrients, the Organic Gardener's Guide to Optimizing Plant Nutrition; Timber Press, Inc.: Portland, OR, USA, 2021.
4. Lowenfels, J.; Lewis, W. *Teaming with Microbes, the Organic Gardener's Guide to the Soil Food Web*; Timber Press, Inc.: Portland, OR,USA, 2021.
5. Séquin, M. The Chemistry of Plants and Insects: Plants, Bugs, and Molecules; Royal Society of Chemistry: UK, 2017.
6. Goldy, R. More Reasons for Soil Testing. MSU. Available online: https://www.canr.msu.edu/news/more_reasons_for_soil_testing (accessed on 10 December 2020).
7. Perera-Castro, A.; Flexas, J. Recent advances in understanding and improving photosynthesis. *Faculty Reviews* **2020**, *9*.
8. Croce, R.; Carmo-Silva, E.; Cho, Y.B.; Ermakova, M.; Harbinson, J.; Lawson, T.; McCormick, A.J.; Niyogi, K.K.; Ort, D.R.; Patel-Tupper, D.; Pesaresi, P. Perspectives on improving photosynthesis to increase crop yield. *The Plant Cell* **2024**, *36*, 3944–3973.
9. Massimi, M. Foliar Plant nutrition and Plant Health Status Interactions. Doctoral Dissertation, University of Debrecen, Debrecen, Hungary, 2024.