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Dietary Phytochemicals in Commonly Consumed Vegetables as a Potential Selective Pressure for Antimicrobial Resistance: A Scientific Postulation

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Abstract

Antimicrobial resistance (AMR) is a major public health concern that threatens the effectiveness of medicines used to treat bacterial infections. Although the inappropriate use of conventional antibiotics is a well-established driver of resistance, the possible contribution of repeated exposure to naturally occurring antimicrobial compounds in foods such as vegetables. Deserves scientific investigation. Many edible plants contain phytochemicals, including alkaloids, flavonoids, phenolic compounds, terpenoids and sulfur-containing compounds, some of which demonstrate antibacterial activity under experimental conditions (Cowan, 1999; Górniak et al., 2019). In addition, plant-derived natural products have contributed to pharmaceutical research and the discovery of biologically active compounds. This paper presents the postulation that repeated dietary exposure to phytochemicals from certain commonly consumed vegetables could potentially expose intestinal bacteria to concentrations that are insufficient to inhibit bacterial growth completely. Such exposure may be relevant to bacterial adaptation or enable organisms to develop antimicrobial resistance if the compounds remain biologically active at sub-inhibitory concentrations. This postulation proposes a research direction for examining whether dietary phytochemicals may represent an overlooked environmental exposure relevant to bacterial adaptation and antimicrobial resistance.
Keywords: Antimicrobial resistance, vegetables, phytochemicals, alkaloids, sub-inhibitory concentrations, bacterial adaptation, dietary exposure.

1. Introduction

Antimicrobial resistance occurs when microorganisms develop the ability to survive or grow despite exposure to antimicrobial agents that would ordinarily inhibit or kill them. Resistance can make infections more difficult to treat and can reduce the effectiveness of available medicines. Although resistance can

emerge naturally, the misuse and overuse of antimicrobial medicines accelerate its development and spread (World Health Organization [WHO], 2025).

Research on antimicrobial resistance has traditionally focused on conventional antibiotics used in human medicine, veterinary medicine and agriculture. However, plants also produce a wide range of biologically active substances as part of their natural chemical defence systems. Some of these substances can affect bacterial growth, bacterial membranes, enzymes, biofilm formation and other microbial processes (Cowan, 1999; Górniak et al., 2019).

Humans regularly consume vegetables, herbs, spices and other edible plants containing these naturally occurring compounds. Examples of commonly consumed plant foods include bitter leaf (Vernonia amygdalina), scent leaf (Ocimum gratissimum), fluted pumpkin leaves (Telfairia occidentalis), garlic (Allium sativum) and ginger (Zingiber officinale). Their chemical composition differs, and some contain compounds that have demonstrated antimicrobial activity in laboratory investigations. Nevertheless, the presence of a phytochemical in a plant does not automatically mean that the plant, when eaten, produces an effective antibacterial concentration inside the human body.

A further consideration is that plant compounds can be isolated, extracted, concentrated and analysed to determine their chemical composition and biological activity. Researchers may identify particular compounds with potential pharmaceutical applications, investigate their mechanisms of action and determine the concentrations required to inhibit bacterial growth. Such laboratory preparations can differ substantially from the quantities and chemical forms consumed in an ordinary meal.

This raises a question for scientific investigation: Could repeated exposure of bacteria to certain dietary phytochemicals present in vegetables, at concentrations below those required for effective bacterial inhibition, contribute to bacterial adaptation or reduced susceptibility? The present paper proposes this possibility as a research hypothesis. It does not claim that eating vegetables has been established as a cause of antimicrobial resistance.

2. Plant-Derived Compounds, Vegetables and Pharmaceutical Research

Plants contain numerous secondary metabolites, commonly referred to as phytochemicals. These include alkaloids, flavonoids, phenolic compounds, terpenoids, tannins and sulfur-containing compounds. Their functions in plants vary, but some can influence the growth and survival of microorganisms (Cowan, 1999; Górniak et al., 2019).

Plant-derived compounds are also important in pharmaceutical research. Natural products have served as sources of medicines, drug leads and chemical structures that researchers can modify to improve their therapeutic properties. Newman and Cragg (2020) describe the substantial contribution of natural products and their derivatives to drug discovery.

It is important, however, to distinguish between a plant containing a biologically active compound and a finished pharmaceutical product containing a purified, standardised active pharmaceutical ingredient (API). A compound identified in an edible plant may be investigated for pharmaceutical use, but this does not mean that the plant itself contains the same standardized dose found in a medicine. Nor does it mean that every edible plant contains a compound suitable for use as an API.

In pharmaceutical research, plant materials may undergo extraction, fractionation, purification and chemical analysis. Researchers can then quantify individual compounds and test their biological activity at known concentrations. These processes help determine which substances are responsible for observed effects and how much of a compound is required to produce a particular response. For example, laboratory studies have investigated plant-derived compounds such as carvacrol, a constituent associated with oregano and other aromatic plants, for their antibacterial activity.

Certain plant-derived compounds can affect bacteria under controlled experimental conditions. However, the results obtained using purified compounds or concentrated extracts cannot automatically be applied to people consuming ordinary portions of vegetables. The quantities of phytochemicals present in foods, their stability during cooking, their absorption and metabolism, and their concentrations within the intestinal environment must all be considered.

3. Statement of the Postulation

This paper postulates that repeated dietary exposure to certain antimicrobial phytochemicals from commonly consumed edible plants may, under particular conditions, expose intestinal bacteria to sub-inhibitory concentrations that could contribute to bacterial adaptation or reduced susceptibility.

The central idea is based on the relationship between the concentration of an antimicrobial substance and its effect on bacterial growth. Some vegetables contain phytochemicals that demonstrate antibacterial activity in laboratory experiments. However, the concentration of an individual compound in a serving of food may differ considerably from the concentration used in an experiment to inhibit bacterial growth. Furthermore, the quantity that ultimately reaches intestinal bacteria may be affected by digestion, absorption, metabolism, food preparation and interactions with other substances in the gastrointestinal tract. Consequently, the presence of an antibacterial phytochemical in a vegetable does not necessarily mean that eating the vegetable exposes bacteria to an antibacterial concentration.

The proposed concern arises if a compound reaches bacteria in a biologically active low concentration that affects their growth without inhibiting the entire bacterial population. Under suitable conditions, such exposure could impose a selective pressure favouring bacteria that tolerate the compound better than others.

4. Scientific Basis of the Postulation

4.1 Antimicrobial phytochemicals occur naturally in edible plants

Many edible and medicinal plants contain compounds that demonstrate antibacterial effects in laboratory studies. These compounds belong to different chemical groups, including alkaloids, flavonoids, terpenoids, phenolic compounds and sulfur-containing phytochemicals. Depending on the compound and the bacterial species tested, they may interfere with bacterial membranes, enzymes, biofilm formation and other cellular processes (Cowan, 1999; Górniak et al., 2019).

Garlic, for example, contains sulfur-containing compounds that have been investigated for antimicrobial activity. Other edible plants and herbs also contain substances that may inhibit bacterial growth under experimental conditions. Nevertheless, the activity of a plant extract depends on its chemical composition, preparation, concentration and the organism being tested. A positive result obtained using a concentrated extract does not establish that eating the corresponding plant produces the same effect inside the body. This distinction is important because the present postulation concerns ordinary dietary exposure rather than the direct application of concentrated extracts to bacteria in a laboratory.

4.2 Concentration influences antimicrobial activity

The antibacterial activity of a compound is influenced by its concentration, the microorganism being investigated and the conditions under which exposure occurs. In microbiology, the minimum inhibitory concentration (MIC) is the lowest concentration of an antimicrobial agent that prevents visible growth of a microorganism under specified test conditions. A sub-inhibitory concentration is one below the MIC, meaning that it does not completely inhibit visible bacterial growth under those conditions.

A compound can therefore demonstrate antibacterial activity at one concentration but have a weaker effect at a lower concentration. This is one reason why researchers determine MIC values rather than relying solely on the presence of an antimicrobial substance. For example, researchers may extract a plant compound, quantify it and test a range of concentrations against a bacterial strain. They may find that a particular concentration inhibits growth while lower concentrations do not.

If bacteria are exposed repeatedly to a biologically active concentration below the inhibitory threshold, the effect may differ from that observed when the compound is used at a concentration sufficient to inhibit growth. However, the MIC of a purified compound in a laboratory cannot simply be used to predict what happens after a person eats a vegetable. The concentration of the compound that reaches bacteria in the intestine would first need to be established.

4.3 Ordinary dietary exposure may differ from concentrated laboratory preparations

An important distinction exists between consuming a vegetable as food and administering an isolated compound at a measured concentration. When researchers investigate plant materials, they may use

solvents, extraction procedures or purification methods to obtain a preparation containing a higher concentration of particular chemical constituents than would be present in the original food portion. The resulting extract can then be tested under controlled laboratory conditions.

By contrast, a person eating vegetables consumes a mixture of water, fibre, nutrients and numerous plant chemicals. The concentration of a particular phytochemical varies with plant species, variety, maturity, growing conditions, storage and preparation. Cooking may also alter the amount or chemical form of certain compounds. Following consumption, digestion, absorption, metabolism and interactions with the intestinal environment may further influence the amount of a compound available to bacteria.

Consequently, a vegetable may contain a phytochemical with antibacterial activity, yet the amount reaching intestinal bacteria may be too low to produce the degree of inhibition observed in a laboratory experiment thereby allowing the bacteria that survive this invasion to develop antimicrobial resistance. The proposed research question is therefore not simply whether vegetables contain antibacterial compounds. It is whether specific compounds from specific foods can reach intestinal bacteria at concentrations that affect bacterial growth or survival without fully inhibiting the exposed population.

4.4 Repeated sub-inhibitory exposure may create selective pressure

Bacteria can adapt to environmental stresses through several mechanisms, including changes in gene expression, physiological adjustments and genetic mutations. When an antimicrobial substance inhibits some bacteria more strongly than others, the less susceptible organisms may have a survival or reproductive advantage under the relevant conditions. If these conditions are not met, the proposed mechanism may not occur. They therefore form the basis of the hypothesis that requires testing.

4.5 Could reduced susceptibility extend to conventional antibiotics?

An additional question is whether adaptation to a plant-derived compound could affect bacterial susceptibility to conventional antibiotics. This is a separate question from whether bacteria become less susceptible to the original phytochemical. Resistance to one substance does not automatically mean resistance to another substance with a different chemical structure or mechanism of action. Nevertheless, some bacterial mechanisms, such as changes in membrane permeability, stress responses and efflux systems, can influence susceptibility to multiple antimicrobial substances.

Al-Mnaser and Woodward (2020) identified mutations in genes associated with bacterial survival and efflux-related resistance mechanisms in variants selected during exposure to particular phytochemicals. Research should therefore distinguish among three outcomes:

- **Reduced susceptibility to the phytochemical itself:** Bacteria become less susceptible to the plant-derived compound used during exposure.
- **Cross-resistance:** The same bacterial changes reduce susceptibility to one or more other antimicrobial agents.
- **Co-selection:** Exposure to one substance favours bacteria that also possess resistance to another substance, potentially because the relevant traits are genetically or biologically linked.

Determining whether any of these outcomes follows exposure to compounds obtained from commonly consumed vegetables would require direct evidence.

5. Proposed Conceptual Model

The postulation can be represented by the following sequence:

Consumption of selected vegetables or edible plants
↓
Ingestion of naturally occurring phytochemicals
↓
Digestion, absorption, metabolism and transformation of the compounds
↓
Possible exposure of bacteria to biologically active concentrations
↓
Potential sub-inhibitory effects on susceptible bacterial populations
↓
Possible survival or selection of bacteria with reduced susceptibility under repeated exposure
↓
Antimicrobial Resistance developed after several consumptions.

This model describes a possible mechanism rather than an established sequence of events in people who consume vegetables. Each stage requires investigation. In particular, researchers must establish whether relevant phytochemicals reach intestinal bacteria in sufficient quantities, whether they remain biologically active, and whether the resulting exposure produces measurable changes in bacterial susceptibility.

6. Research Implications and Future Directions

The postulation provides a basis for developing a research programme to examine the relationship between dietary phytochemicals and bacterial susceptibility.

6.1 Identification and quantification of phytochemicals

The first step would be to select specific vegetables or edible plants and identify the phytochemicals responsible for their reported antibacterial activity. Quantitative analytical methods could then be used to determine the concentrations of the selected compounds in the foods or prepared extracts. This stage would help distinguish between the mere presence of a phytochemical and the amount actually available for exposure. It would also allow researchers to compare the concentrations found in food with concentrations tested in antibacterial experiments.

7. Limitations of the Postulation

This paper presents a scientific hypothesis rather than the results of an experiment. The limitations must therefore be acknowledged.

- Although some plant-derived compounds have demonstrated antibacterial activity, their activity varies with concentration, chemical composition and bacterial species.

8. Conclusion

Edible plants contain a diverse range of phytochemicals, some of which demonstrate antibacterial activity and have attracted interest in pharmaceutical research. This paper postulates that, under particular conditions, repeated exposure of intestinal bacteria to biologically active but sub-inhibitory concentrations of certain dietary phytochemicals contribute to bacterial adaptation or reduced susceptibility. The purpose of this postulation is not to discourage vegetable consumption, but to propose a testable scientific question about the possible relationship between dietary phytochemicals, bacterial adaptation and antimicrobial resistance. Until appropriate evidence is available, this relationship should be treated as a hypothesis requiring investigation rather than an established cause of AMR.

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