Chapter 11

Potential Adverse Effects of Alteration of Phytochemical Accumulation in Fruits and Vegetables

Sechene Stanley Gololo

Additional information is available at the end of the chapter

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Abstract

Alterations in the accumulation of phytochemicals in fruits and vegetables may have adverse effects on the health benefits emanating from their consumption. Plants parts possess secondary metabolites in addition to their primary metabolites. Plants secondary metabolites possess many inherent biological activities that include antimicrobial, anti-inflammatory, and enzyme inhibitory properties, which are health benefits to humans. Accumulation of phytochemicals in plants is reportedly influenced by environmental factors or growth conditions such as lack of nutrients, pathogens attack, competitive co-habitation plant species, insect predation, and herbivorous attack. Human interventions such as agricultural practices may affect biochemical processes in plants or crops in a manner that may limitations or alterations in the accumulation of phytochemicals. The limitation of phytochemicals accumulation in fruits and vegetables may have the adverse effect on their health benefits in humans that may explain the high prevalence of life style diseases such as diabetes and cancer experienced in today's world. The proper assessment of the influence on phytochemical responses in crops, fruits, and vegetables by modern agricultural practices such as weeding methods, herbicides, insecticides, fertilizer application, crop rotation, and co-habitation needs to be carried out. Such assessment is important since while crop production may be improved, caution should be exercised not to erode, or negatively alter phytochemical biosynthesis in crops.

Keywords: plant metabolites, phytochemicals, biological activities, phytochemical accumulation, environmental conditions, weeding methods, herbicides, insecticides, fertilizer application, crop rotation, crop co-habitation

1. Introduction

The purpose of this chapter is to highlight the potential adverse effects of phytochemical accumulation alterations in fruits and vegetables on the well-being of people. The chapter deals with the introduction of plant metabolites with the distinguishing between primary and secondary metabolites based on their roles in plants. The chapter also deals with the biosynthesis and accumulation of phytochemicals in plants that are based on the effects of different environmental factors on phytochemical compositions in plants. This includes the review of the effect of pesticides on phytochemicals in agricultural products through comparison on products produced by organic farming and conventional farming. The potential adverse effect of phytochemical accumulation limitation in fruits and vegetables on the well-being of people is also highlighted through the discussion of the health benefits of the actions of phytochemicals in prevention and treatment of diabetes and cancer.

2. Plant metabolites

In addition to nutritional value, consumption of fruits and vegetables also provide health benefits to humans due to the nature of their secondary metabolites [1]. Plants of all kinds, including fruits and vegetables, possess two types of metabolites with distinct roles known as primary and secondary metabolites as shown in **Figure 1**. Primary metabolites, generally possessed by all plants, are metabolites that contribute to the plants' growth [2]. Primary plant metabolites include carbohydrates, lipids, proteins, and nucleic acids. Secondary metabolites, sometimes found in specific plants or plants parts, are for the performance of protection

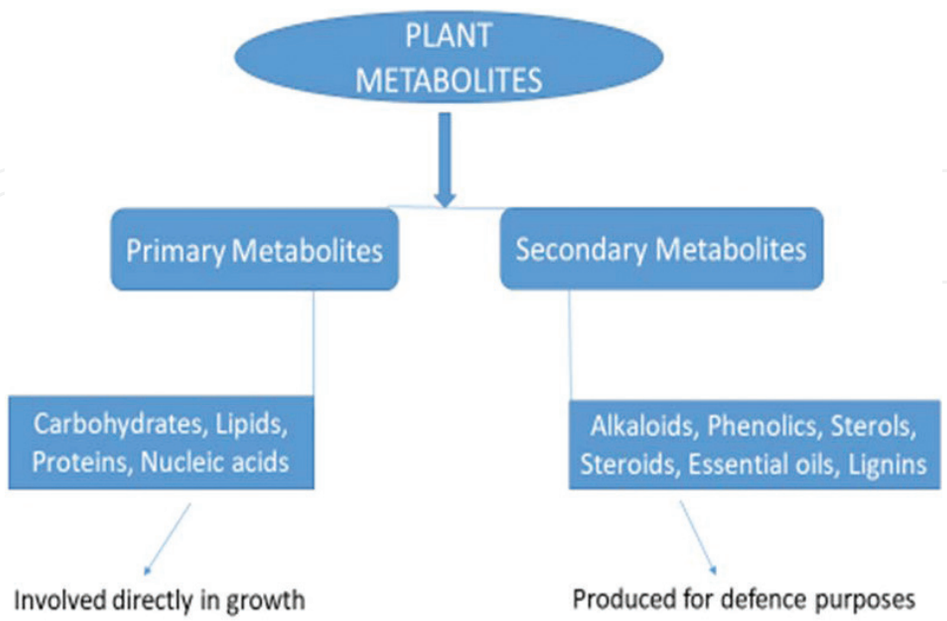

Figure 1. Plant metabolites and their different roles in plants.

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functions from threats that emanate mainly from external factors [3]. Secondary plant metabolites include alkaloids, phenolic compounds, sterols, steroids, essential oils and lignins, and are commonly known or referred to as phytochemicals.

3. Biosynthesis and accumulation of phytochemicals in plants

The biosynthesis of phytochemicals in plants is mainly achieved through the Shikimate and the Acetate-Mevalonate pathways [4], as shown in **Figure 2**. Most end-products of the catabolic metabolism of primary metabolites serve as precursors for the biosynthesis of a range of secondary metabolites that are commonly referred to as phytochemicals. Aromatic amino acids enter secondary metabolite biosynthesis via the Shikimate pathway. The Shikimate pathway leads to the production of simple compounds such as gallic acid and *p*-coumaric acid that are precursors to complex products like tannins and nitrogen-containing phytochemicals [5]. Acetyl-CoA, an end-product of carbohydrate metabolism, leads to the biosynthesis of terpenes and steroids through the Acetate-Mevalonate pathway [6].

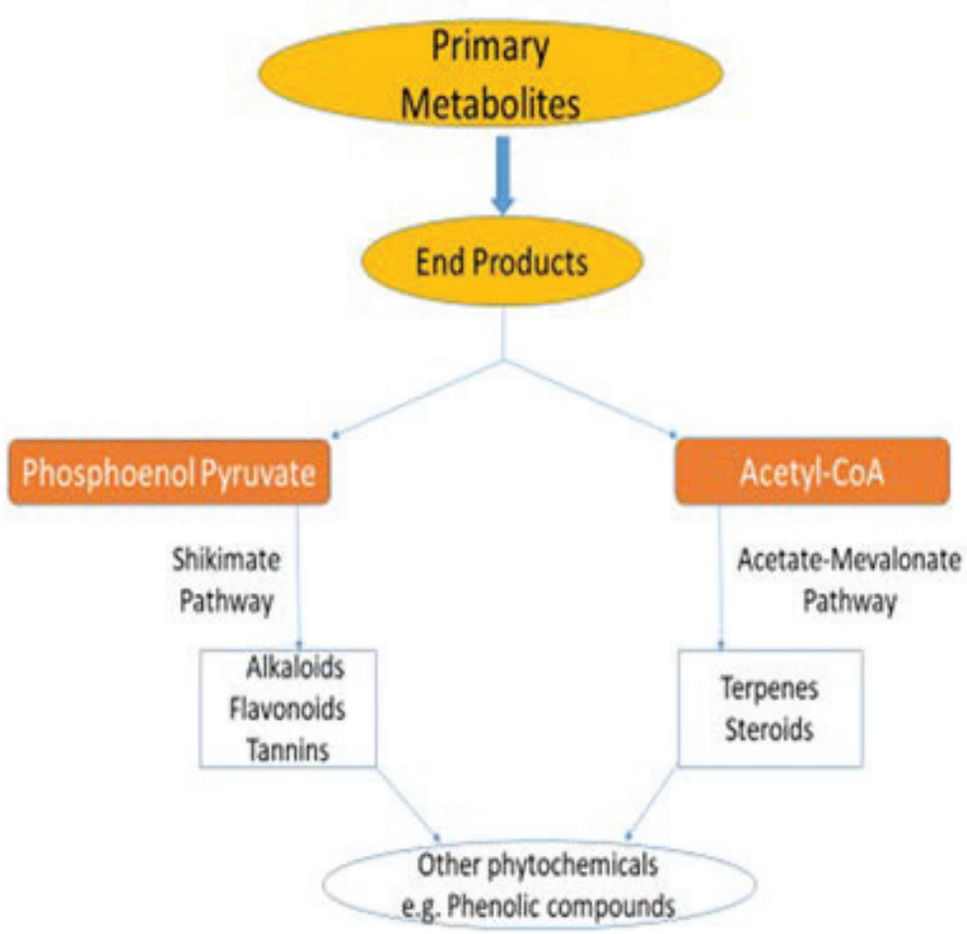

Figure 2. Biosynthesis of phytochemicals.

The biosynthesis of phytochemicals in plants, as described above, is reported to be also induced by external stimuli [7]. As such, phytochemical compositions of plants are mostly found to differ both qualitatively and quantitatively depending on the exposure or susceptibility to the stimuli [8]. The external stimuli that induce phytochemical biosynthesis in plants may be summed up through environmental factors under which plants grow. Environmental factors under, which plants grow and affect their phytochemical compositions may include geographical location parameters such as altitudes and soil types, seasonal variations, and exposure to pollution [9]. In the case of fruits and vegetables, such environmental factors may also include agricultural practices such as the use of insecticides and herbicides. Some findings on the effects of certain agricultural practices on the presence and accumulation of phytochemicals in fruits and vegetables, as well as their implications on people's health are discussed below.

3.1. Effects of agricultural practices on phytochemicals in fruits and vegetables

Undisputedly, the introduction of pesticides (synthetic) like insecticides and herbicides in the period between 1970 and 1980 contributed to increased agricultural productions. However, this intervention in agriculture has had some unintended results toward human life. The criticism of the usage of pesticides is mainly based on their direct cause of fatal health challenges and chronic diseases due to their poisonous effect upon exposure [10]. However, in addition, the potential consequences of the limitations in the phytochemical accumulations by agricultural plant products are not being given adequate attention or canvassing in the public discourse.

The effect of pesticide application on the phytochemical accumulation in fruits and vegetables could be assessed through the comparison of phytochemical quantities between crop products produced through organic farming, which does not involve the use of synthetic pesticides, and those produced through conventional farming that uses synthetic pesticides. In this regard, organic farming was reported to have been given yield to sweet pepper (*Capsicum annum*) of higher intensities in color (both red and yellow); higher mineral contents and higher total carotenoids than those produced through conventional farming [11]. In addition, the same study reported that highest antioxidant activity was found in red peppers produced through organic farming. In a separate study, a higher ratio of reducing sugars/organic acids, as well as high amounts of total sugars, vitamin C, and total flavonoids were recorded in tomato fruits produced by organic farming compared to those of conventional farming practice [12]. According to Oliveira et al. [13], the accumulation of more phytochemicals such as phenolics and vitamin C in tomato fruits from organic farming was a result of the stressing conditions associated with the farming system. It thus follows that conventional farming practice reduces or remove stressful growing conditions that then limit the accumulation of important phytochemicals in crops. The demonstration through some studies that the production of food products through conventional farming methods with the excessive use of insecticides and herbicides may limit the accumulation of phytochemicals in fruits and vegetables necessitate the assessment of potential implications of such limitations on people's health.

The quality and quantity of phytochemicals in plants depend on a number of factors that include the growing environment. Organic farming inherently provides a different growing

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environment compared to conventional farming, which relies heavily on inputs such as pesticides, synthetic fertilizers, and excessive irrigation. The growing environment in organic farming exposes plants and crops to biotic stress due to pests and diseases [14]. Herbivore and pathogen attack lead to enhanced biosynthesis and accumulation of defense-related phytochemicals in fruits and vegetables [15]. Deficiency of nitrogen, phosphate, and iron that emanate from non-application of synthetic fertilizers in organic farming contribute to the accumulation of phenolic compounds in fruits and vegetables [15]. Drought or less irrigation associated with organic farming also induce accumulation of polyphenols and total tannins in crops through the activation of the phenylalanine ammonia-lyase enzyme that is involved in the biosynthesis of phytochemicals in plants [16].

3.2. Potential adverse effects of phytochemical accumulation alterations in plant products

In Africa, people have relied on consumption of fruits and vegetables for many years with no profound problems of life style diseases. Fruits and vegetables are known to possess phytochemical compounds with biological activities that have the ability to prevent and reverse the development of chronic diseases such as diabetes and cancer [17, 18]. Therefore, a question arises as to how come the world, Africa in particular, is today burdened with the advent of life style diseases such as diabetes and cancer in the midst of massive agricultural production of fruits and vegetables. The answer to this imminent question may lie in the understanding of the possession or the presence of plant metabolites in fruits and vegetables, more especially the accumulation of secondary metabolites that are commonly referred to as phytochemicals.

The secondary metabolites found in different plants parts; including fruits and vegetables, possess many biological activities. Amongst the biological activities exerted by different phytochemicals are the enzyme inhibitory properties. There are two enzymes that are reported to contribute to the fast postprandial release of glucose from a carbohydrate-rich meal, namely the alpha-amylase and alpha-glucosidase. Inhibitory actions of these enzymes that are inherent in some phytochemicals present in plant products such as fruits and leafy vegetables contribute to the regulation of blood glucose levels as the slow release of glucose from diet sources may afford its proper metabolism, which mitigate against the development of diabetes mellitus [19]. Carbohydrates are of course important dietary requirements to supply living organisms with the necessary energy for growth. However, malfunctioning or poorly regulated carbohydrate metabolism may lead to the rapid postprandial release of glucose into the bloodstream with potential discrepancies in its further breakdown. The advent of discrepancies in the breakdown of glucose may result in its accumulation in blood, which gives rise to the potential development of diabetes mellitus [20].

In addition, the enzyme inhibitory properties inherent in some phytochemicals may affect kinases that are involved in cell cycle progression, which may contribute to the mitigation against the development of cancer. Cancer is a disease of uncontrolled cell growth, which is propelled through up-normal continuous cell division cycle [21]. Cell division cycle progression is regulated through the activity of phosphorylation enzymes known as kinases [22]. Cell division cycle progression is also depended on the intactness of the DNA that is safeguarded

by the action of tumor suppressor genes. Tumor suppressor genes act by way of effecting cell division cycle arrest in case of DNA damage that affords DNA repair or cell death. One of the major causes of DNA damage is oxidative stress that emanates from the imbalances between reactive oxygen species (ROSs), known as free radicals and antioxidants. In the case, where DNA damage results in the malfunctioning of tumor suppressor genes, cell division cycle continues even in situations, where it should not of which the result is uncontrolled cell growth. Oxidative DNA damage may also affect metabolism regulatory genes that may lead to inadequate or impaired insulin. As such, oxidative DNA damage may culminate in the development of diseases such as cancer and diabetes mellitus [23]. The continuous supplementing of the human body with antioxidants is an important intervention that contributes immensely to the attainment of a balance between ROSs and antioxidants, which reduces oxidative stress. Consumption of fruits and vegetables contribute to the replenishing of the body with antioxidant as they are sources of phytochemicals with antioxidant properties [24].

Explanation of the molecular basis of diseases such as diabetes and cancer brings forth the understanding that adequate consumption of fruits and vegetables may result in the prevention and reversal of these conditions [18]. In the case of diabetes, high blood glucose levels, complications arise from the accumulation of glycated proteins known as advanced glycation end-products (AGEs). Antioxidation, one of the known major biological activities of phytochemicals is reported to contribute to the prevention of the formations of AGEs [25], as well as having protective effects against AGEs induced in stem cells [26]. As such, the immediate question is what contributes to the escalation of the prevalence of these diseases as well as escalated fatalities they cause, in the midst of massive production of fruits and vegetables that is taking place. The answer to this question may lie in understanding the biosynthesis and accumulation of phytochemicals in fruits and vegetables. The accumulation of phytochemicals in plants parts are reported to be for plants survival or defense mechanism in response to adverse environmental influences. Such environmental influences may include pathogens attacks, competitive co-habitation plant species, insect predation, and herbivorous attack. This exposure to hostile environmental settings mainly occurs in wild set-ups. Plants have been shown to have both qualitative and quantitative differences in their phytochemical compositions when growing under varying conditions [27]. In today's world, crops and plantations are shielded from hostile environmental conditions due to modern agricultural practices that also include the use of insecticides and chemical weed removals (herbicides). While production targets may be improved and attained [10], these modern agricultural practices may lead to the alteration of phytochemical compositions accumulation in agricultural products such as fruits and vegetables. Phytochemical accumulation alterations in plants may creep in since the threat that induces biosynthesis of phytochemicals would have been removed. This alteration in the accumulation of phytochemicals in fruits and vegetables may have adverse effects on human health such as inadequate availability of phytochemicals with antidiabetic and anticancer properties. As such, while production could be optimized through modern agricultural practices the quality of the agricultural produce may be negatively affected in terms of their phytochemical compositions. Thus, caution should be exercised not to erode or negatively alter the phytochemical biosynthesis patterns in fruits and vegetables in pursuit of massive production. Alternatively, agricultural practices could include the creation of conditions that will induce bioaccumulation of phytochemicals in fruits and vegetables.

4. Conclusion

Plants products, including fruits and vegetables, generally possess two types of chemicals that play different roles known as primary and secondary metabolites. Secondary metabolites are produced for defense purposes in plants in response to detrimental environmental stimuli and contribute to the well-being of humans upon consumption due to their disease prevention and reversal properties. However, modern agricultural methods, although with improved production yields, may give rise to phytochemical accumulation alterations in agricultural products such as fruits and vegetables that eventually have negative effects on their health benefits in human beings. The extent, to which modern agricultural practices may affect the accumulation of important phytochemicals in fruits and vegetables still needs to be fully determined, which presents scope for future research.

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Conflict of interest

The author declares no conflict of interest.

Author details

Sechene Stanley Gololo

Address all correspondence to: stanley.gololo@smu.ac.za

Department of Biochemistry, School of Science and Technology, Sefako Makgatho Health Sciences University, Pretoria, South Africa

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