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Phytochemicals in Herbs: A Review of Commonly Consumed Herbs for Health and Disease in Northern Nigeria

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ABSTRACT

Phytochemicals are biologically active compounds found in plants, responsible for mitigating effects in various diseases, including cancer, inflammatory diseases, cardiovascular disorders, and rheumatic disorders. Northern Nigeria is rich in herbs, such as *Calotropis procera, Azadirachta indica, Anogeissus leiocarpus*, garlic and many more, which have been shown to possess phytochemicals with numerous medicinal properties. This review aimed to explore the phytochemicals and their mechanisms of action in commonly used herbs in Northern Nigeria. A comprehensive literature search was conducted using Google Scholar, PubMed, and Research Gate. The review revealed that herbal supplements consumed in Northern Nigeria contain significant amounts of phytochemicals, including flavonoids, phenols, saponins, tannins, terpenoids, and cardiac glycosides. These compounds exhibit antioxidant, anti-thrombotic, anticancer, anti-inflammatory, antibacterial, and anti-arteriosclerotic properties. A notable shift in the consumption of herbs has been observed across all socio-economic classes in Nigeria, driven by the perceived health benefits and the high cost of prescribed drugs and healthcare services. In conclusion, the need for regulatory agencies at all levels of government to ensure the safe use of herbs and minimize adverse effects is emphasized. Furthermore, increased funding for research on medicinal plants is necessary to fully explore their potential benefits.

Keywords: Phytochemicals; herbs; health; diseases; Northern Nigeria

INTRODUCTION

Over the last 30years, the herbal supplementation market has exponentially grown, with over half a thousand herbs marketed in the USA. In Africa over 80% of its population are using traditional medicine in primary health care (Ilomuanya, 2023). Traditional herbs play a crucial role in Nigeria's healthcare, serving as accessible and affordable alternatives for primary health needs. The global herbal medicine market is projected to grow from 83billion in 2019 to 550 billion by 2030, with China and India as leading exporters. Europe imports over 400,000 tonnes annually to meet local demand for medicinal plants . Herbal medicines are perceived as having minimal side effects, drawing on their long history of use by diverse populations worldwide (Nath et al., 2023).

A good number of people are not aware of the potential harmful effects of herbal medicines. Because of this reason, WHO allow the incorporation of Traditional Medicine (TM) and Complementary Alternative Medicine (CAM) into the National Health Care Systems of member countries and to encourage the

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development of national policy and regulations for their use within a national health care system. (WHO, 2021). Benefits derived from the use of herbal supplements are numerous such as amla and green tea,which are recognized for their role in disease prevention and treatment, particularly in cancer and cardiovascular health (Kausar et al., 2024).

Phytochemicals are chemicals of non-nutrient compounds that are biologically active and are naturally present in plants, including fruits, vegetables, legumes, grains, herbs, tea, and spices. They comprised of polyphenol which makes up the largest and diverse group of phytochemicals. Polyphenols dietary intake stood at about 1 g per day. (Monika Thakur, 2020) . As the intake of herbal supplements increases exponentially, this review aimed at understanding the phytochemicals found in commonest herbal supplementation consumed in our locality that gives the derived benefit to those that consume them.

BACKGROUND ON PHYTOCHEMICALS

Phytochemicals are powerful, naturally occurring compounds found in various plant-based foods, including fruits, vegetables, legumes, grains, herbs, and spices. These bioactive compounds come in many forms, such as carotenoids, flavonoids, phenolic acids, and phytosterols. Phytochemicals have been shown to have numerous health benefits, as they can regulate various cellular processes, including inflammation, cell growth, and metabolism, ultimately helping to prevent chronic diseases (Kausar et al., 2024).

Numerous epidemiological and clinical studies have demonstrated that a diet rich in vegetables, fruits, and whole grains can significantly lower the risk of chronic diseases, such as heart disease, diabetes, and certain cancers. Additionally, consuming diets high in healthy fats (e.g., mono and polyunsaturated fats), soy proteins, and nuts has been shown to have a positive impact on cardiovascular health, including improving lipid profiles and lowering blood pressure, as well as reducing cancer risk (Lalitha, 2024).

Polyphenolic group are the largest group of phytochemicals. From the name polyphenolic, they are those compounds with more than one phenol structure. The average daily dietary intake of polyphenols is approximately 1 gram (Lalitha, 2024).

Polyphenols, comprising over 8,000 compounds, can be grouped into four main categories depending on the number of phenol rings - flavonoids, phenolic acids, stilbenes, and lignans - with flavonoids being the largest and most diverse class. (El Gaamouch Farida et al, 2022).

Flavonols, primarily quercetin and kaempferol, are widely present in various foods. The richest sources include onions, leafy greens like kale and broccoli, fruits like apples and blueberries, beverages like red wine and tea, and the herb ginkgo biloba (Kandar, 2022).

The second subgroup is Flavanols, and can be named according to the number of bonds in their chemical structure. Those with single bond are referred to as catechins and those with multiple bonds are called based Proanthocyanidins or tannins. Tannins give foods and drinks a drying, puckering sensation (Kandar, 2022).

The dietary intake of flavonoids varies depending on the country, region, and pattern of food intake. Although it is essential to consider the different classes of flavonoids when consuming a diet. Available data shows that Europe has the highest number of studies stating the amount of flavonoid intake, with the highest in the UK due to high consumption of tea (350-600 mg/day). In Australia, a country with high black tea consumption, flavonoid intake has reached

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650-700 mg/day. In America, especially in the USA, the average intake of flavonoid stood at 250-400 mg/day, This is largely due to the relatively low consumption of fruits and vegetables in the USA., with the highest flavonoid intake coming from tea consumption. In Asia, especially in China, flavonoid intake ranges from 65-225 mg/day, due to high consumption of green tea compared to black tea (Escorba-Ce'voli et al, 2017).

The recommended daily intake of flavonoids is 400 to 600mg which has the benefit of cardiometabolic health aimed at reducing cardiovascular disease globally (Hancocks, 2022).

The other subgroup of flavonoid family includes flavones, such as luteolin and apigenin, which are found in limited amounts in foods like parsley and certain cereals. Flavanones, another subgroup, comprise a small number of compounds, including naringenin in grapefruits, eriodictyol in lemons, and hesperetin in oranges. A single serving of fruit juice, such as orange juice, can provide 40-140 mg of flavanone glycosides. Anthocyanidins, the aglycone form of anthocyanins, are powerful plant pigments responsible for the red, blue, or purple hues of many fruits and vegetables. Berries are an exceptionally rich source, with a 100g serving providing up to 500mg of anthocyanins (Hussain et al., 2022).

The other subgroup of flavonoids is the isoflavones that are mostly found in legumes, especially soybeans, alfalfa and beans (Gomez-Zorita et al 2020).

Isoflavones, along with lignans (found in seeds, whole grains, nuts, and certain fruits and vegetables) and coumestans (present in broccoli and sprouts), belong to the phytoestrogen group. The two primary plant-based isoflavones are genistein and daidzein (Zaheer K. et al., 2021). Although flavonoids comprise a significant portion of the thousands of phytochemicals, many other phytochemicals are also present in various foods. Scientific evidence suggests that isoflavones may alleviate several postmenopausal symptoms, including hot flashes, osteoporosis, and certain cancers, such as breast and prostate cancer. (Zaheer K. et al 2021).

In addition to flavonoids, other notable phytochemicals include phenolic acids, carotenoids, terpenes, and glucosinolates. Recently, phenolic acids have garnered significant attention due to the global surge in coffee consumption. As a rich source of phenolic acids, coffee contains compounds derived from hydroxybenzoic acid and hydroxycinnamic acid. The primary dietary hydroxycinnamic acids are caffeic, ferulic, p-coumaric, and sinapic acids. Among these, caffeic and ferulic acids are the most commonly consumed, with estimated daily intakes ranging from 500 to 1,000 mg, particularly among regular coffee drinkers (Foss et al., 2022).

Hydroxycinnamic acids are not exclusive to coffee; they can also be found in various vegetables, whole grains, and fruits, such as blueberries, tomatoes, and apples. Hydroxybenzoic acids, including ellagic and gallic acids, are abundant in red wine, tea, nuts, and berries.

Interestingly, plant-based foods often contain a diverse array of phytochemicals - for instance, tomatoes alone can harbor up to 10,000 different phytochemicals. Furthermore, the composition, digestibility, and absorbability of these phytochemicals can be influenced by factors such as the plant species, climate, ripeness, storage methods, and processing techniques.

Phytochemicals in food exist in various forms, which affect their digestion and absorption. Many polyphenols, for instance, are found in

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foods as glycoside conjugates. Some of these glycosides must be broken down into their unconjugated forms, known as aglycones, before being absorbed. Other phytochemicals can be absorbed in the small intestine without extensive digestion. However, many phytochemical glycosides remain undigested and unabsorbed in the small intestine. Research suggests that the absorption of most phytochemicals involves carrier-mediated mechanisms, primarily occurring in the intestines and stomach. Interestingly, certain phytochemicals that evade absorption in the small intestine can undergo microbial degradation by the gut microbiome, as seen with Ellagitannin. (Dixit, 2021).

The gut microbiome breaks down glycosides into aglycones, which can undergo further metabolic transformations to produce aromatic acids. Some of these acids may be absorbed into the bloodstream from the colon. Once absorbed, polyphenolic metabolites are typically conjugated in the liver or small intestine through methylation, sulfation, or glucuronidation. These conjugated metabolites then bind to plasma proteins like albumin and are transported in the blood. However, the levels of these metabolites in the bloodstream vary greatly depending on factors such as the type and amount of polyphenol consumed, as well as its food source. Despite extensive research, the metabolism of various polyphenols and the resulting plasma metabolites are not yet fully understood. Studies have highlighted significant differences in the metabolic pathways of numerous phytochemicals (Foss et al., 2022)

Notwithstanding the limitations of existing research, phytochemicals are widely recognized to have numerous vital functions in the body.

ROLES AND MECHANISM OF ACTION OF PHYTOCHEMICALS

Role as Antioxidant

Flavonoids are embedded in cell membranes, situated between the aqueous and lipid bilayers, where they exert antioxidant effects in the body. Specifically, flavonoids can neutralize free radicals, including hydroxyl, peroxyl, alkyl peroxyl, and superoxide radicals, thereby terminating chain reactions. Two key characteristics determine a flavonoid's effectiveness as an antioxidant: (1) Its ability to donate a hydrogen atom from its phenolic hydroxyl group to free radicals, similar to vitamin E.

(2) The capacity of its phenolic ring to stabilize unpaired electrons.

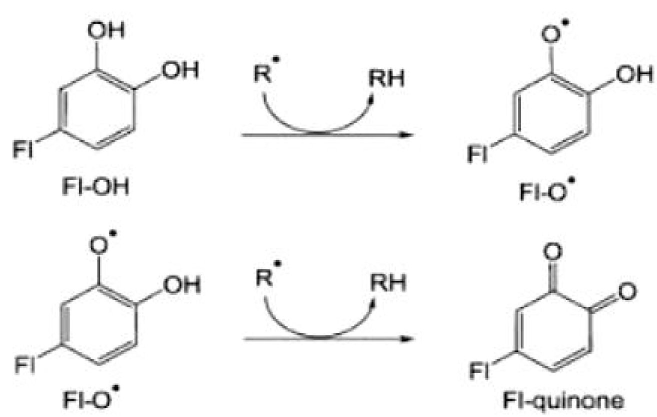

Figure 1: Mechanism of flavonoids action as antioxidant modified from Nijveldt et al., (2001).

Flavonoids exhibit additional antioxidant mechanisms, as reported by Nijveldt et al. (2001). These include:

I. **Modulation of Nitric Oxide**: Flavonoids can interfere with inducible nitric oxide synthase activity, thereby reducing the excessive production of nitric oxide. Elevated nitric oxide levels can react with free radicals, forming the damaging peroxynitrite, which causes oxidative stress. Flavonoids can scavenge both nitric oxide and other free radicals, preventing peroxynitrite formation (Rodríguez et al., 2023).

II. **Inhibition of Xanthine Oxidase**: Flavonoids, such as quercetin and silibin, have been found to inhibit xanthine oxidase, reducing the formation of superoxide free radicals. This occurs when xanthine oxidase reacts with molecular oxygen (Nijveldt et al., 2001).

III. **Gene Expression Modulation**: Another important mechanism of flavonoids is by stimulating the expression of specific genes that produces antioxidant defense. It upregulate Superioxide dismutate, catalase that helps scavenge ROS (Rodríguez et al., 2023).

Furthermore, antioxidant activity is not exclusive to flavonoids. Other polyphenols, lignans (found in various plant-based foods), carotenoids (abundant in brightly colored fruits and vegetables), and resveratrol (present in grapes and peanuts) also exhibit antioxidant properties.

Role as Anti-Inflammatory Agent

Studies have shown that, phytochemicals also play important role in inflammatory process by inhibiting the inflammatory effect through inducing anti-inflammatory effect (Corona-España et al., 2024)

In a study conducted by Corona-España et al. (2024) demonstrated that incubating RAW 264.7 cells with Wild Grapes Procyanidins (WGP) significantly suppressed inflammatory responses by downregulating the protein expression of iNOS and COX-2. Similarly, the research found that polyphenols present in red wine and black tea, such as quercetin, EGCG, ECG, and flavins, inhibited COX-2 and LOX in a dose-dependent manner when applied to LPS-activated murine macrophage RAW 264 cells.

Curcumin, a phytochemical abundant in turmeric, has been extensively studied for its wound-healing properties. Beyond its use as a food spice, turmeric has been traditionally applied topically to treat skin wounds, including ulcers by fibroblast cell proliferation and migrations (Syafri et al., 2024).

Role as Estrogenic

Beyond their antioxidant properties, certain lignans and isoflavones exhibit estrogen-like effects. Phytoestrogens, such as those found in soy proteins, undergo biotransformation by intestinal microflora, followed by absorption and entero-hepatic recycling, ultimately reaching circulating levels that can match or even surpass those of endogenous estrogen. Isoflavones, for instance, structurally resemble estrogen, enabling their phenol ring to bind to estrogen receptors on body cells. As a result, soy products rich in isoflavones have been marketed to alleviate symptoms associated with decreased natural estrogen levels during peri-menopause in women (Canivenc-Lavier & Bennetau-Pelissero, 2023).

Role as Antitumor

Glucosinolates, isothiocyanates, terpenes, and certain phenolic acids, such as hydroxycinnamic acid, have been found to exhibit protective effects against tumor formation, largely due to their antioxidant properties

Reactive oxygen species (ROS) can cause DNA damage, leading to mutations when cells with unrepaired or misrepaired DNA divide. If these mutations occur in critical genes, such as oncogenes or tumor suppressor genes, they can initiate or promote tumor growth. Furthermore, ROS can directly interfere with cell signaling and growth pathways. The cellular damage caused by ROS can trigger mitosis, increasing the likelihood of mutations, and enhance the exposure of DNA to mutagens (Saha et al., 2024).

Role as Antiatherosclerotic

Isoflavones and phytosterols have been found to have cholesterol-lowering properties, which may help reduce the risk of heart disease. They influence biochemical and signal transduction pathways, contributing to the prevention and treatment of atherosclerosis as such soy products rich in isoflavones and margarines fortified with phytosterols are being promoted as dietary options for individuals with hypercholesterolemia (Enayati et al., 2021).

Epigallocatechin gallate (EGCG) another key anti-atherosclerotic phytochemical. Its mechanism of action include regulating lipid metabolism, improving endothelial function, inhibiting inflammatory factors, modulating inflammatory signaling pathways, and reducing platelet aggregation, thereby contributing to the prevention of atherosclerosis and related cardiovascular diseases (Liu et al., 2024).

Calotropis procera (Tumfafiya)

Calotropis procera, commonly known as Tumfafiya in Hausa, is a member of the *Asclepiadaceae* plant family. This tall, erect shrub can grow up to 6m in height, with a large, much-branched structure and milky latex throughout (Misha Jayswal, 2022).

Calotropis procera is widely used in traditional medicine globally, with various parts of the plant, including leaves, roots, bark, stems, and flowers, being utilized to treat a range of ailments, such as coughs, colds, fevers, asthma, indigestion, rheumatism, elephantiasis, leprosy, and certain types of cancer (El-Ghani, 2016).

Calotropis procera is a rich source of various phytochemicals that contribute to its extensive therapeutic potential. The plant contains triterpenoids, flavonoids, cardiac glycosides, and phenolic compounds, which are linked to numerous pharmacological activities, including antimicrobial, anti-inflammatory, and anticancer effects. The mechanisms through which these phytochemicals exert their effects are diverse and multifaceted (Rabêlo et al., 2023).

A study conducted by Misha Jayswal (2022) has shown that the methanolic extract of *Calotropis procera* contains a majority of these phytochemicals, while the aqueous extract contains alkaloids, saponins, and a small amount of cardiac glycosides (Misha Jayswal, 2022).

Tumfafiya as Antihelmintic and Antimicrobial: Mechanism of Action

Calotropis procera, commonly known as Tumfafiya, is widely used in traditional animal healthcare (ethno-veterinary medicine) for its antihelmintic, purgative, expectorant, anti-inflammatory, laxative, and diuretic properties (Iqbal et al., 2005). Similarly, Aggarwal R et al. (2016) reported that various parts of *C. procera*, including its latex, exhibit emetic, purgative, and anthelmintic effects in traditional medicine.

Abubakar et al. (2024) examined the root of *C. procera* and found it to be effective in staphylococcus aureus infection, and salmonella typhi indicating its potential as a rich source of bioactive compounds and a viable alternative to antibiotics for treating infectious diseases.

Plant metabolites can interact in an additive, synergistic, or antagonistic manner, targeting one or multiple sites. Therefore, it is likely that multiple compounds contributed to the antihelmintic activity observed in the plant extracts (Abubakar et al., 2024).

The benzimidazole antihelmintics have been found to exert their effects by disrupting the microtubule system in Ascaris suum (Aggarwal R et al., 2021). Similarly, it is possible that Calotropis procera (C. procera) exerts its antihelmintic effects through a similar mechanism. The complete paralysis of worm tissues, likely caused by the plant's bioactive compounds, renders them unable to feed, ultimately leading to death due to energy depletion.

Furthermore, the high concentration of alkaloids present in C. procera may have contributed to the paralysis and subsequent death of the worm (Aggarwal R et al., 2021).

Table 1: Summary of Extract of *Calotropis procera* (Tumfafiya) and its Uses

PART	PHYTOCHEMICALS	USES	REFERENCE
Extract of Latex and leaves	cardenolides, steroid glycoside and flavonoids	Antioxidant, anti-inflammatory, anti-tumor and anti-microbial	(Rabêlo et al., 2023)
Root acqueos extract	tannin, saponin, alkaloids, phenolics, flavonoids, and reducing sugars, with terpenoids	The extracts demonstrated significant antimicrobial activity against Staphylococcus aureus, Salmonella typhi, Klebsiella pneumoniae, Candida albicans, and Aspergillus flavus	(Abubakar et al., 2024)
hydroalcoholic extract of the leaves	Alkaloids, glycosides, sugars, tannins, flavonoids, and steroids	The in-vivo studies reduced inflammation of rats from formalin. It concluded that c. procera is a potent anti-inflammatory	(Singh et al., 2024)

Anogeissus leiocarpus (DC.) Guill and Peer (Marke)

Anogeissus leiocarpus (DC) Guill and Peer, a member of the Combretaceae family, is commonly known by various names, including African birch, Axle wood tree, "Marke" or "Farin gamji" in Hausa, and several other local names (Dahiru & Musa, 2023).

This tree species typically grows to a height of 15-18 meters, with a trunk diameter of up to 10cm. Its bark is grayish-beige in color, with thin scales, while its leaves are acute at the apex, attenuated at the base, and pubescent below (Julienne Kuiseu, 2021).

The phytochemical composition of *Anogeissus leiocarpus* is responsible for its therapeutic benefits. Studies on the plant's root have identified various phytochemicals, including catechical tannins, gallic tannins, flavonoids, leuco-anthocyanins, saponosides, free anthracenics, and coumarins (Julienne Kuiseu, 2021).

These phytochemicals were found in varying concentrations, with tannins, leuco-anthocyanins, and saponosides being more abundant than flavonoids in the leaf powder.

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Traditionally, *Anogeissus leiocarpus* has been used to treat various ailments, including diabetic ulcers, general body pain, blood clots, asthma, coughing, jaundice, piles, and tuberculosis (Bakarnga-Via et al., 2022).

Table 2: Summary of phytochemicals from *Anogeissus leiocarpus* and there uses.

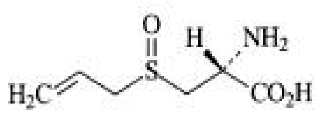
PART	PHYTOCHEMICALS	USES	REFERENCE
Stem bark Methanolic extract	flavonoids, tannins, and saponins.	Extract of 200mg and 400mg significantly ($p<0.05$) increased the anti-ulcer activity	(Datok et al., 2022)
Leaf ethanolic extract	saponin, flavonoids, steroids, alkaloids, tannins, glycosides and phlobatannins	Used as Antibacteria to many bacteria e.g Staphylococcus aurea, streptococcus pneumonie, Escheria coli and Pseudomonas aeroginosa	(Akharaiyi, 2024)
Acqeous extract of leaves	Phytochemical analysis indicated presence of terpenoids, saponins, steroids, glycosides, flavonoids, tannins and alkaloids	The results indicate that identified compounds, particularly 3-dihydro-indol-2-one, could be responsible for the anti-inflammatory, anti-nociceptive, and anti-pyretic properties of the extract.	(Idakwoji et al., 2022)

Garlic (Tafarnuwa)

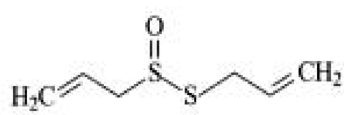
Garlic (*Allium sativum*) belongs to the *Amaryllidaceae* family and the genus Allium. In Hausa, it is known as Tafarnuwa. Garlic shares similarities with onions, chives, and leeks, as they all belong to the same family and contain sulfur-containing amino acid derivatives, primarily S-allyl-L-cysteine sulfoxide, also known as alliin (El-Saadony et al., 2024).

When garlic cells are damaged, such as through cutting or chewing, the enzyme alliinase converts alliin into allicin (diallyldisulfide-S-oxide). Allicin then breaks down into diallyl disulfide, the primary compound responsible for garlic's odor, and ajoene (Sasi et al., 2021) .

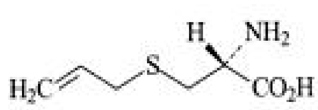
Notably, some garlic components, like aged garlic extract, do not contain allicin but have still been linked to various health benefits



Alliin



Allicin



S-Allyl-L-Cysteine

Figure 2: Alliin, Allicin and S-Allyl-L-Cysteine Biochemical Composition.

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Garlic is considered one of the oldest medicinal plants, with a long history of use. It is widely consumed globally, incorporated into various dishes, beverages, and used as a spice. Many people use garlic to alleviate symptoms of the common cold and flu. Additionally, recent studies suggest that garlic may have potential benefits in combating COVID-19 infection (Ibrahim B. A. et al, 2022). Phytochemical analysis of garlic has revealed the presence of various compounds, including flavonoids, tannins, steroids, saponins, terpenoids, phenolics, alkaloids, and cardiac glycosides (Almatroodi, 2020). The active components of garlic, primarily classified as organosulphides, have been shown to exhibit antilipidemic, antithrombotic, antihypertensive, anticarcinogenic, antiglycemic, antioxidant, and immune-enhancing properties (Okoro et al., 2023) (Pandey et al., 2023).

CONCLUSION

In conclusion, phytochemicals are abundant in natural foods, herbs, and spices, playing a crucial role in maintaining our overall health and well-being. Given the rising global health challenges, including communicable and non-communicable diseases, coupled with increasing living costs, especially in developing countries, many individuals focus on herbal remedies for health preservation and disease treatment. This shift has led to a surge in the global herbal market, spanning America, Europe, Asia, and Africa.

While phytochemicals in herbs offer numerous health benefits due to their bioactive compounds, they can also have harmful adverse effects. Therefore, it is essential to establish close regulations and conduct further clinical trials to ensure the safe and effective use of herbal remedies.

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