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Biological Components in Cucumbers (*Cucumis Sativus* L.): Implications for Pickle Manufacturing and Health Benefits in Fresh and Processed Varieties

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Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

This comprehensive review delves into the botanical intricacies of *Cucumis sativus* L., commonly known as cucumbers, and their pivotal role in pickle production within the realm of food science. The investigation systematically scrutinizes the health benefits associated with both unprocessed and processed cucumber varieties, shedding light on the intrinsic bioactive elements present in cucumbers and their potential contributions to human well-being. Emphasizing a meticulous exploration of the molecular interplay, the review unveils the complex mechanisms that underlie the purported health advantages of cucumbers. Phytochemical constituents, such as antioxidants and anti-inflammatory agents, are scrutinized for their potential implications in promoting wellness. By synthesizing scientific literature and empirical evidence, the review not only serves as a valuable resource for researchers but also extends practical insights for professionals in nutrition and food science. The bridging of theoretical understanding with practical applications distinguishes this review, offering a nuanced perspective on the molecular facets of cucumber compounds. Its implications extend beyond academic discourse, influencing considerations in food processing strategies and dietary recommendations. In essence, this review seeks to unravel the scientific intricacies of cucumber bioactive elements, providing a substantive foundation for comprehending their potential health benefits, especially in the context of pickled

cucumber consumption.

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Keywords: Cucumber, Phytochemical, Antioxidants, Health Benefits.

1. Introduction

Belonging to the herbaceous vines family, the cucumber encompasses 118 subgroups and 825 types.^{[1][2][3]} While originating in Asia, members of the herbaceous vines family are widely distributed across hot and semitropical regions globally. Cucumber stands out as one of the most sought-after cucurbits, appreciated for its nutritive ethics, health advantages, and prolific production.^{[3][4][5][6]} Cucumbers have extensive growth in Europe, contributing significantly with an annual growth that constitutes 26.7% of the total vegetable production in the region^{[2][7][8]}. Beyond its role as a nutrient-rich food source, cucumber has been utilized in mental medicines and cosmetology since earliest times, highlighting its versatility in various domains.^{[5][9][10]}

True, cucumber is characterized by its high water percentage and low calorie count, making it a hydrating and low-energy addition to dietary choices.^[11] Indeed, cucumbers, classified as a vegetable crop, are abundant in phenolic acids and various phytonutrients, contributing to their nutritional profile^[12]. These compounds in cucumbers are known for exhibiting a range of biological activities, including antioxidant, anti-carcinogenic, anti-hyaluronidase, anti-elastase, hypolipidemic, anti-inflammatory, antihyperglycemic, diuretic, amylolytic, antimicrobial, and analgesic properties.

Cucumber fruits vary in size, ranging from 3 cm to over 30 cm long. Typically slightly rounded and porous, they become smooth and shiny when young. While most fruits are green, some may be white or yellow, and the pulp is characterized by a pale green or white color^[13]. The shape of cucumbers is influenced by factors like cultivation, production area, and processing methods (Figure 1).

In pickle formation, cucumbers are preserved by immersing them in a mixture of sodium chloride or acetic acid, undergoing a fermentation process^{[3][14][15]}. Gherkin pickling not only enhances the taste and appearance but also preserves the nutritive values of cucumbers. Its attraction extends to nutritive and medically gained aspects, including

possible advantages against diabetes problems, heart problems (attributed to monounsaturated fats), and the availability of special small parts such as phenolics [9][11][16][14]. Use of cucumber is advised for brain diseases, dementia treatment, and stopping different allergies such as under-eye pimples and hyperpigmentation. Additionally, cucumbers are believed to enhance chilling, alleviating, relaxing, moisturizing, and abirritant effects on annoying skin.

This review exclusively delves into the nutritional and highly effective biological combination view, along with the healthcare and working characteristics of both fresh and prepared cucumbers. Subsequent sections elaborate on various antioxidant and nutritive benefits associated with this versatile food.

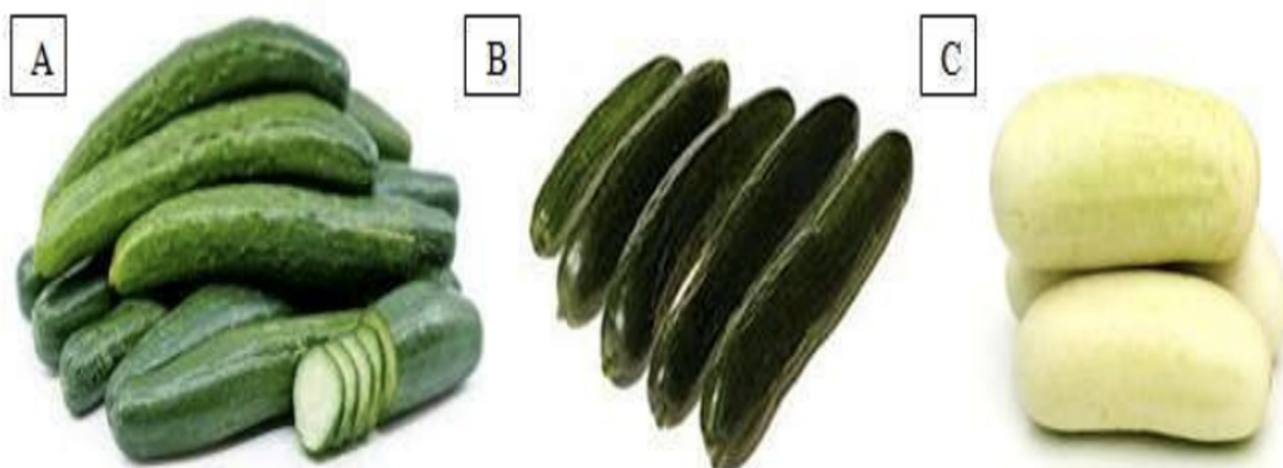


Figure 1. A) Different types of cucumber fruits: B) Types of green cucumbers, used for pickle production C) Types of white cucumbers.

2. Nutritive Composition

Chemical composition significantly influences cucumber quality. *Cucumis sativus* L. (cucumber) shares nutritional similarities with pickles [3]. A 100g serving of cucumber is primarily water, containing proteins, fats, and carbohydrates. Dietary fiber, promoting digestive health, is also present [2][12][13][17][18][19][20]. Notably, pickles consist of 95% water, with modest protein (0.6%), lipids (0.1%), and carbohydrates (2.2%) [2] (Table 1). Carbohydrate content is calculated by deducting moisture, protein, fat, and ash percentages from 100. Raw cucumbers contain 2.16g of carbohydrates per 100g, including fiber (0.7g), sugars (1.37g), glucose (0.64g), fructose (0.74g), and starch (0.09g) [20]. Additionally, cucumber provides various vitamins, minerals, and antioxidants.

Studies report cucumber moisture content around 73-95%, influenced by factors like variety and growth conditions [17]. The fruit's composition varies based on the environment, affecting nutritional content. Recent research highlights the correlation between water content, phytochemical composition, and the final product's stability during cucumber processing [18][19].

Cucumber offers essential vitamins and antioxidants [2][21][16]. Pickles are rich in vitamin B1, ascorbate, B-complex vitamins, macro, and micro minerals [12]. While micro and macro elements are present, their bioaccessibility can be

hindered by compounds like Ethanedioic acid and IP6 [13][20]. Cucumber is notably high in calcium, potassium, and sodium, with lower copper, manganese, and iron accessibility [13][20]. Potassium's mobility in plants influences enzymatic reactions and contributes to production quality [22]. Cucumber fiber comprises both insoluble and soluble types, playing diverse roles in nutrition [22]. Manganese is essential for bodily functions, while zinc and copper are vital for immune health and enzyme function [17][23][24][25][26]. Deficiencies in these elements can impact physical and cognitive health.

Phytochemicals	Value/100 g (unit)	Phytochemicals	Value/100 g (unit)
Energy	15 kcal	Vitamins	
Water	95.23 g	Vitamin C, total ascorbic acid	2.8 mg
Protein	0.65 g	Thiamin	0.027 mg
Total lipid (fat)	0.11 g	Riboflavin	0.033 mg
Carbohydrates, by difference	3.63 g	Niacin	0.098 mg
Fiber, total dietary	0.5 g	Vitamin B ₆	0.040 mg
Sugars, total	1.67 g	Folate, DFE	7 µg
Minerals		Vitamin B ₁₂	0.00 µg
Calcium	16 mg	Vitamin A, RAE	5 µg
Iron	0.28 mg	Vitamin A, IU	105 IU
Magnesium	13 mg	Vitamin E (α-tocopherol)	0.03 mg
Phosphorus	24 mg	Vitamin D (D ₂ + D ₃)	0.0 µg
Potassium	147 mg	Vitamin D	0 IU
Sodium	2 mg	Vitamin K	16.4 µg
Zinc	0.20 mg		
Lipids			
Fatty acids, total saturated	0.037 g	Fatty acids, total polyunsaturated	0.032 g
Fatty acids, total monounsaturated	0.005 g	Cholesterol	0 mg

Table 1. Nutritional value of cucumber per 100g (3.5 oz)

3. Pickle Production

Pickled fruits typically have a normal size to width ratio of around 3, appearing mostly long and three-sided. Smooth, spineless, and constantly colored fruits are normally adopted. Domestic to hot areas, the yearly plant can grow up to 2-3m in length with cubic stems. In Indo-European hothouse farming, stems are managed by around strained strings. The flowers are similarly gendered, basically requiring allogamy, but modern non-fertilized types can bear fruit without pollination. Pickled fruits from these types will have minimal to no seeds [14].

The pickles are sorted as follows:

The world's largest pickles are utilized to create "sour bombs" and can also be found in rollmops, a dish featuring rolled herring with a pickle inside [27].

- i. **Harvesting** Pickles can flourish in various soil varieties, provided there's adequate land shaping and clean water

delivery. Depleted, weary land with high humus content is preferred. Growing is viable in gardens or hothouses, with hothouse-grown crops yielding 6 to 11 times more than those in normal soil. Greenhouse cutting of crops spans from July to October. While most pickles are grown outdoors, not in greenhouses, normal cutting of crops is essential to stimulate new crop growth. As pickles grow larger, increased plant energy expenditure reduces the overall harvestable quantity.

ii. **Processing:** There are two methods of pickle processing.

1. **Processing into sour-sweet pickles:** For the manufacturing of sour-sweet pickles, pickles from class A to C are utilized. When packing category E fermented veggies, they are pre-punctured to prevent gas formation. The pickle preparation involves washing, typically done in brush washers or drum washers. These washed pickles are then filled in acid-resistant glass or cans containing necessary herbs like yellow mustard seeds, onions, and bay leaves. Filling is carried out using a hand-loading table or a band-filling machine. Once filled, a covering liquid, consisting of water, vinegar, salt, sugar, and optional aromatic spices, is added. To prevent spoilage post-opening, a small amount of preservative may be included. The jars and cans are sealed, with acid-resistant external respirated lids for jars. The product undergoes pasteurization in a pasteurization tunnel, generally at a temperature of 80 to 82°C. Pasteurization time is adjusted by controlling the belt speed to ensure sufficient microorganism elimination while maintaining product crispiness. After pre-heat treatment, the preserves are fastly chilled.
2. **Salted pickle processing:** In times of surplus pickle production, extra pickles undergo fermentation in large containers to extend their storage life. The whole pickle fruits are washed before refinement, irrespective of their intended type. Following washing, pickles are punctured using a machine to create holes, facilitating quick salt absorption. Pickling involves placing pickles in tanks under the 4-7% brine solution for fermentation. The salt in the mixture inhibits toxic microorganism growth while enabling *Lactococcus lactis* to thrive. Salt also prompts cells to extract water vapour, supporting lactic acid bacteria growth. This fermentation, whether natural or initiated with an axenic culture, allows better quality control. If using the axenic culture method, pickles are first washed with water containing under 110 to 160 ppm chlorine to finish natural microbes. The controlled fermentation takes 3-7 weeks, converting sugars into lactic acid and carbon dioxide, resulting in under 0.4 to 0.9% lactic acid production. Post-fermentation, the brine solution gradually increases by 3% weekly until reaching 15%, coupled with lactic acid for effective pickle preservation.

Before further processing pickles into sour pickles or piccalilli, the temporarily preserved pickles undergo desalination. This process involves immersing the pickles in running water for approximately two days.

iii. **Storing:** The last step in pickle production includes mentioning the manufacturing date on the packaging containers, which can then be stored at room temperature for an extended time.

Food, Shelter & Sanitation Design: If a product maintains a high acidity level ($\text{pH} < 4.6$), the risk of germ cells evolving into vegetational microbes that could damage or pollute the product is lessened. Consequently, sterilization becomes unnecessary. Mild pasteurization, along with rapid cooling, proves enough to eliminate vegetational cells without significantly altering the flavor. The tartness level in the brining fluid or the mixture of sourness and salt in briny pickles

only permits the growth of *Lactococcus lactis*, enhancing product solidity early in the manufacturing procedure. Manufacturing equipment and hardware must be visibly clean, meeting good manufacturing practice (GMP) standards. In cases where machinery cannot be fully emptied, thorough cleaning and disinfection are necessary before restarting the production process. While light microbial pollution may not pose a significant problem, cleaning off salt should occur at fridgidity and with potable water. If water is recirculated, this part of the procedure must adhere to toxic design standards. When the covering is complete, the product undergoes tempering. Although this doesn't diminish the importance of careful attention to cleanliness during the pre-preparation stage, and preparational apparatus should still be fully cleaned, a large quantity of thermostable hygienic produced by microbes can remain hygienic after heat treatment, posing a potential threat to consumer fitness.

4. Health Benefits

Cucumbers offer a range of health benefits, enhancing overall well-being. Their high moisture content and essential nutrients make them a valuable addition to a balanced diet, providing a refreshing and hydrating option [28]. Cucurbitacin B, a natural compound abundant in cucumbers, displays potential as an anticancer agent by inducing apoptosis in various human cancer cells [29]. In research conducted by Gao et al., cucurbitacin B demonstrated significant chemopreventive activity against human prostatic adenocarcinoma [29]. Cucumber peel, known for its rich fiber content, can aid in reducing cramps and potentially contribute to colon health by eliminating toxins considered as a whole from the stomach, offering potential reassurance in colon cancer. Addressing complications associated with diabetes, including neurological dysfunction, renal failure, and heart failure, becomes crucial as diabetes mellitus continues to rise [30]. Cucumbers, containing special antioxidants like caricaxanthin, epsilon-carotene, ascorbate, retinol, xanthophyll, and 3'-diol, serve as protective agents against oxygenes alkyl. Redox imbalance and free radical damage, influential factors in diabetes progression, generate free radicals and weaken the body's antioxidant protecting systems [31][32]. Numerous substances and organic combinations show promise in alleviating complications associated with diabetes insipidus. Heidari et al.'s research suggests that cucumbers may have a protective effect against diabetes by reducing oxidative and carbonyl stress [4][5][32]. Cucumber juice offers benefits for the beauty of humans. Prolonged sun exposure induces the production of antioxidants in the skin, leading to oxidative stress and inflammation in connective tissues. This process contributes to aging, cell membrane damage, and harm to organic molecules, as highlighted in studies (references [16][33][34]).

Hyaluronate and a special protein for skin are essential for maintaining tendon energy, which diminishes with aging [35]. Cucumbers, identified as a rich source of vitamin C, show possibility as Hyaluronate 4-glycanohydrolase and Anti-ESI, supporting their use as possible age prevention compounds [16]. The soothing and cooling effects of cucumber on the skin are commonly employed for addressing issues like puffiness under the eyes and sunburn [11][16]. Cucumbers are a main resource of silicon, a mineral important for tendons, ligaments, and cartilage health [13][36]. Organically brewed sour pickles, preserved with brine and Sarcolactic acid, are bacteriologically protected, nutritive, and have a prolonged shelf life without refrigeration, as indicated by studies (references [27][37]). The presence of healthy *Lactococcus lactis* in brewed cucumbers adds to their health benefits. Lactose-brewed cucumbers contain beneficial microbials that can help prevent

the growth of harmful microbes in the gut [3]. Pickled fruits exhibit a mild water pills effect due to their high water and potassium content, along with low sodium content, making them valuable for weight control and managing high blood pressure. Additionally, cucumbers, a main source of antihemorrhagic, play a crucial role in developing bone mineral density (BMD). Their high potassium content contributes to lowering blood pressure [17]. Beyond their delicious taste, cucumbers are recommended for treating hypertension and limiting neuron damage in Alzheimer's patients [38][39]. Cucumber is believed to offer various skin benefits, including preventing under-eye swelling, sunburn, and soothing irritated skin with its cooling, healing, and anti-itching effects [11].

5. Conclusion

Cucumbers are a highly nutritious food that contains many bioactive substances. They are used in various ways, including for medicinal purposes, beauty care, and insect control. Cucumbers are popular for their many biotic activities, such as free-radical scavenging, antitumour, anti-swelling, and germicidal effects, as well as their capability to regulate glucose levels in the blood, promote diuresis, and provide pain relief. Fresh cucumbers can help prevent diabetes and hypertension, treat Alzheimer's disease, prevent cancer, and slow down the aging process. Fermented cucumbers, on the other hand, are a great source of fiber and probiotics. This review gives a comprehensive sketch of the nutritional, phytochemical, and health benefits of cucumbers to maximize their health benefits.

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