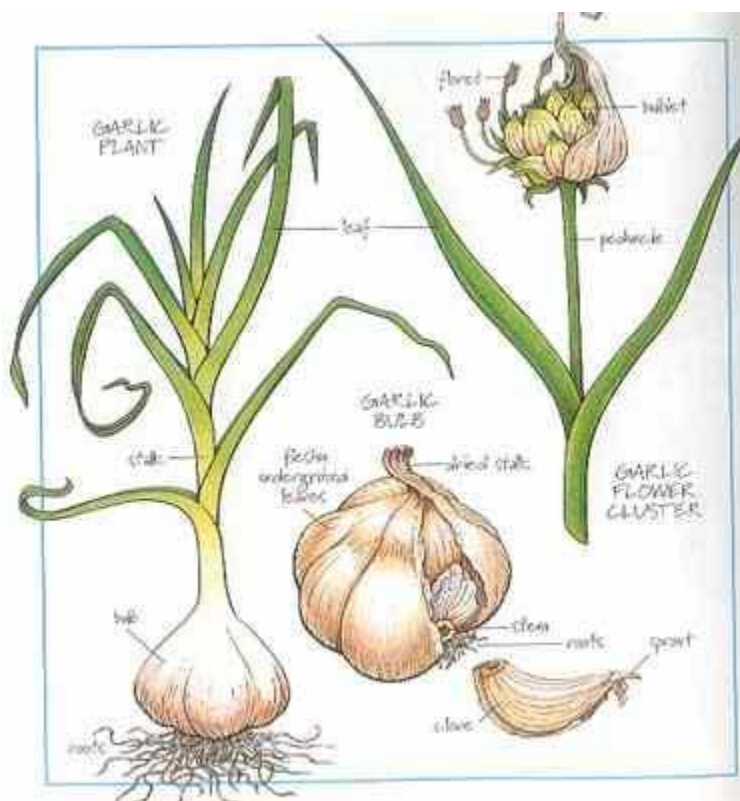


# Diallyl disulfide



*"And, most dear actors, eat no onions nor garlic, for we are to utter sweet breath..."*

*- Shakespeare, Midsummer Night's Dream*



## ABSTRACT:

This paper focuses on the phytochemical properties of diallyl disulfide, an organosulfur compound found in allium relatives such as garlic, shallots, onions, and chives. Research on the benefits of eating garlic is presented, followed by a recipe containing many different forms of allium plants. Several qualities of garlic will be discussed, including its anti-carcinogenic, antioxidant, and antiseptic properties. Sensory results of the recipe are recorded, and nutrient facts are provided. Overall, the consumption of garlic and other allium plants can bring about many health benefits ranging from cancer to hyperlipidemia prevention.



## PURPOSE:

The purpose of this experiment is to research the phytochemical properties of diallyl disulfide (DADS) with a focus on garlic, and to produce an original recipe containing the functional foods.



## LITERATURE REVIEW:

### Background

Garlic has been used as food and medicine for over 4000 years (1). During the first Olympic Games in Greece, garlic was used as an ergogenic aid. In China, onion and garlic tea have been used to treat fevers, headache, cholera, and dysentery. In India, garlic has long been used as an antiseptic for cleansing wounds and ulcers. More recently during the two world wars, garlic was also used as an antiseptic to prevent gangrene. In addition to these uses, it has also been associated with treating bites, intestinal worms, and even tumors (1).

Research has shown that medical and biological uses of garlic can be attributed to its high organosulfur compounds content, such as those in the allyl sulfide phytochemical group (1). Phytochemical is an umbrella term that refers to a variety of plant-based compounds that may affect human health (2).

Thousands of phytochemicals have been identified, including carotenoids, ascorbic acid, and folic acid.

The allyl sulfides are found in foods such as garlic, onions, shallots, leek, and chives (3). According to the American Cancer Society, allyl sulfides are associated with antioxidant activity and strengthening the immune system (2).

In Eric Block's *Garlic and other Alliums: The Lore and the Science*, he attributes the belief of the protective and healing powers of garlic in folk medicine to be based on the pungent scent (4). When crushing, grinding, or cutting a garlic bulb, the damage releases the enzyme alliinase, which immediately

transforms alliin into allicin, the source of the pungent smell of garlic (5). Allicin is then transformed into the oil-soluble polysulfides, including diallyl disulfide (DADS). The concentration of DADS depends on the conditions in which the garlic was extracted, such as temperature, time, and the polarity of the solvent (5).

Raw garlic is 65% water, and the majority of the dry weight is fructose containing carbohydrates, sulfur compounds, and protein. Garlic also contains dietary fiber and vitamins A, C, E, B-complex, tocopherols, and riboflavin. Trace elements include zinc, manganese, copper, selenium, and iodine. Raw garlic also has high concentration of polyphenols and a-tocopherols (6).

### Garlic as an anticarcinogen

As mentioned, the protective effects of garlic stems from the presence of organosulfur compounds and the allyl derivatives, which is associated with inhibiting the development of cancers in gastrointestinal tract. Some proposed mechanisms include the ability of organosulfur compounds to control enzyme activity that activates or detoxifies carcinogens and inhibits the formation of DNA in target tissues (3).

There are many epidemiological studies that suggest consuming garlic has anti-carcinogenic properties. One study performed in China compared two populations living in different regions. One on average consumed about 20g of garlic a day, while the other consumed about less than 1g of garlic a day. The study revealed that the population with the high-garlic diet was three times less likely to develop chronic stomach cancer. The authors of the study hypothesized that perhaps garlic inhibited the reduction of nitrates, thereby lowering the concentration of nitrates in gastric juice and decreasing the production of carcinogenic nitrosoamines (5). Another epidemiological analysis that investigated the consumption of garlic with incidence of cancer found that the consumption of large amounts of raw garlic was associated with lower risk of gastric and colon cancer (5). Furthermore, another Chinese study found this association with reduced risk of developing prostate cancer, controlling for other foods and body weight. However, current research on garlic and onion reducing the risk of breast cancer has yielded mixed results (5).

However, the problem with many epidemiological studies is that it often does not account for confounding factors such as consuming vegetables, fruits, and green tea, which also have established links of reducing cancer risk.

The diallyl disulfide compound in garlic has also been found to impede cancer cell growth. In one study, scientists implanted human colon tumor cells in mice and reported that DADS had an inhibitory effect. Because this in vivo experiment highly mimics actual physiological conditions, it is a strong frame of reference for confirming that organosulfur compounds such as allyl sulfides may inhibit some cancers and tumors (5).

The reason why DADS may have cancer inhibiting properties may be due to its ability to decrease the amount of cells in G1 phase, and to inhibit cells in the G2/M phase, thereby effectively inducing cell-cycle arrest. This was seen in an experiment with human colon cancer cells as well as with prostate and bladder cancer cells (5). All these studies were dose and time dependent.

And finally, studies have been performed on how histone deacetylase inhibitors may be used in the prevention and therapy of cancer (7). This is because histone deacetylase can reactivate the expression of silenced genes that influence differentiation, apoptosis, invasion, metastasis, and regulation of cell cycle. It has been found that allyl sulfides inhibit the proliferation of tumor cells, which is associated with increased histone acetylation (7). In addition, DADS has shown to affect the migration and invasion of cancer cells, though the molecular mechanisms have yet to be identified (5).

Even the National Cancer Institute has a page specifically devoted to “Garlic and Cancer Prevention.” Some of the key points that the report focuses on is that there is building evidence that consuming garlic may reduce the risk of several types of cancer, namely those related to gastrointestinal tract. They also highlight that dose response is currently uncertain and high intake could cause gastrointestinal distress (8).

### Cardioprotective properties of garlic

Garlic consumption is also linked with reducing the risk of hyperlipidemia. In a study where rats were monitored for their glucose, cholesterol, and triglyceride levels on varying doses of garlic, there were significant reductions in cholesterol and triglyceride levels even at a low dose of garlic. The authors concluded that high doses of raw garlic had effects on all glucose, cholesterol, and triglyceride levels while boiled garlic had little effect overall (6).

In another study on patients with hyperlipidemia, the effects of a long-acting garlic drug, allicor, was tested on the risk of coronary artery disease. In men that took allicor for 12 months, there was a 10.7% reduction of a “10-year absolute risk of acute myocardial infarction” (6). Another study with diabetic hyperlipidemia patients and garlic powder tablets found that 300mg of garlic powder three times per day for six weeks significantly decreased total cholesterol, LDL levels, and systolic blood pressure.

Finally, oxidation of LDL is known as an instigator of atherosclerosis. Oxidized LDL promotes vascular dysfunction by transforming macrophages to foam cells and by “exerting direct cytotoxicity” toward endothelial cells (6). However, researchers have found that several garlic compounds have successfully inhibited LDL oxidation in vitro and that short-term supplementation of garlic to humans may increase LDL oxidation resistance (6).

### Antioxidant properties of garlic

Positive antioxidant activity is closely linked with cardiovascular health. In a study done on commercial shallot and garlic preparations, samples were tested for antioxidant activity. Researchers found that fresh freeze-dried shallot and garlic extracts had significantly high phenolic compound content than commercial preparations (6).

It has also been reported that long term consumption of garlic increase antioxidant activity in cells. Aged garlic extract scavenges reactive oxygen species in the body as well as enhances “cellular antioxidant activities by increasing glutathione level in the cells” (5).

### Garlic as an antiseptic

As mentioned, traditional medicine had many different uses for garlic. Research has been able to validate some of these uses, such as garlic’s antiseptic properties. Garlic inhibits the growth of gram-positive, gram-negative, and acid-fast bacteria. This can mainly be attributed to the organosulfur compounds diallyl disulfide and diallyl sulfide. These compounds are also associated with protecting against *Helicobacter pylori* infection, which is highly correlated with stomach cancer development (1).

Furthermore, garlic was shown to be effective against many strains of bacteria that are resistant to penicillin, streptomycin, doxycilline, and others (1). This is an area with great research potential due to overuse of antibiotics in modern society.

### Future research

The evidence for garlic is ever expanding, and more and more connections are being made between its traditional uses, modern medication, and future implications.

Currently, data suggests that garlic may even be effective as a biological immune response modifier, and it may help maintain homeostasis of immune function (1). This ability may protect against cancer and damages brought upon by acquired immunodeficiency syndrome (AIDS). However, mechanisms and components of immune stimulation in response to garlic are yet to be fully understood.



## MATERIALS & METHODS:

In this experiment, various relatives of the Allium family will be used in a modern take of the Korean pancake, pajeon, served with a Chinese Hakka inspired dipping sauce. Pajeon is an appetizer that is typically prepared with squid and scallions or with kimchi. In this recipe, there will be a combination of garlic chives and scallions, which are used widely in Eastern Asian cooking. The dipping sauce draws insight from a traditional Hakka sauce used for steamed chicken. The Korean pajeon dipping sauce typically consists of soy sauce and vinegar, however this flavorful Southern Chinese sauce is traditionally prepared with soy sauce and sautéed shallots. This rendition will also include some aromatic rice wine, sesame seeds, and raw garlic and scallion tails.

PAJEON (PANCAKE)	HAKKA SHALLOT SAUCE
- 1 cup white flour	- 4 tbs soy sauce (low sodium)
- 1 cup water	- 4 tbs rice wine
- 1 egg	- 1 tbs canola oil
- ¼ tsp baking powder	- ¼ cup shallots, chopped
- 1 cup garlic chives, chopped	- 2 cloves of garlic, minced
- 1 cup scallions, chopped	- 1 tbs sesame oil
- ½ cup onion, chopped	- 2 tsp sesame seeds
- 1 red pepper, chopped	- 2 tsp scallion tails
- 1 chili pepper, chopped	
- 3 tbs canola oil	

1. Mix together the flour and the baking powder. Add the water and beat in the egg mix until there are no lumps.
2. In a large pan, heat canola oil over medium-high heat with chili pepper.
3. Once heated, mix in garlic chives, scallions, and red pepper. Once slightly browned, pour in the batter. The batter should cover the entire bottom of the pan.
4. Pan-fry the pancake until the edges are visibly cooked. Then carefully flip it over and cook the other side.
5. Pan-fry both sides until golden brown.
6. In the meantime, prepare the sauce. Heat the canola oil and shallots in a small saucepot over high heat. Once browned, add the soy sauce and rice wine. Turn to low heat and simmer until it comes to a boil. Then remove from heat and mix in the garlic and sesame seeds. Top with scallion tails and set aside.
7. Once the pancake is cooked, remove from heat and divide into eight slices. Serve with the sauce on the side.

## RESULTS:



PAJEON (PANCAKE)

Appearance	Texture	Smell	Taste
Browned, flat cake dotted with green and red	Slight crisp, softer and doughy on the inside.	Heavily of garlic chives and scallions.	Savory, doughy

Nutrition Facts		Vitamin A	50.0 %
<b>PAJEON</b>		Vitamin B-12	1.9 %
1 Serving = 2 Slices		Vitamin B-6	10.3 %
Amount Per Serving		Vitamin C	128.2 %
<b>Calories</b>	177.1	Vitamin D	2.4 %
<b>Total Fat</b>	2.8 g	Vitamin E	3.4 %
Saturated Fat	0.5 g	Calcium	3.6 %
Polyunsaturated Fat	0.8 g	Copper	5.8 %
Monounsaturated Fat	1.1 g	Folate	23.4 %
<b>Cholesterol</b>	45.2 mg	Iron	12.8 %
<b>Sodium</b>	24.0 mg	Magnesium	5.0 %
<b>Potassium</b>	232.1 mg	Manganese	19.2 %
<b>Total Carbohydrate</b>	32.2 g	Niacin	11.0 %
Dietary Fiber	2.8 g	Pantothenic Acid	2.3 %
Sugars	0.8 g	Phosphorus	8.7 %
<b>Protein</b>	5.9 g	Riboflavin	13.4 %
*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.		Selenium	15.9 %
		Thiamin	20.0 %
		Zinc	3.6 %

HAKKA SHALLOT SAUCE

Appearance	Texture	Smell	Taste
Dark brown/black liquid mixed with chopped shallots, garlic, and scallion	Slight crunch but otherwise liquidy	Aromatic, garlicky	Savory, garlicky

Nutrition Facts			
<b>HAKKA SHALLOT SAUCE</b>			
8 Servings			
Amount Per Serving			
<b>Calories</b>	58.7	Vitamin A	0.9 %
<b>Total Fat</b>	3.6 g	Vitamin B-12	0.0 %
Saturated Fat	0.4 g	Vitamin B-6	2.5 %
Polyunsaturated Fat	1.3 g	Vitamin C	1.5 %
Monounsaturated Fat	1.7 g	Vitamin D	0.0 %
<b>Cholesterol</b>	0.0 mg	Vitamin E	2.2 %
<b>Sodium</b>	496.7 mg	Calcium	0.8 %
<b>Potassium</b>	38.2 mg	Copper	1.1 %
<b>Total Carbohydrate</b>	5.4 g	Folate	0.7 %
Dietary Fiber	0.1 g	Iron	1.4 %
Sugars	3.4 g	Magnesium	1.3 %
<b>Protein</b>	0.7 g	Manganese	4.0 %
		Niacin	1.0 %
		Pantothenic Acid	0.5 %
		Phosphorus	1.6 %
		Riboflavin	1.0 %
		Selenium	0.5 %
		Thiamin	0.7 %
		Zinc	0.6 %

\*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.



## CONCLUSION:

The recipe created for this experiment is an alternative take to pajeon, a Korean pancake. I chose to alter a pajeon recipe instead of a scallion pancake recipe because scallion pancake requires the creation of a dough that is typically kneaded with butter or lard, and then deep fried. Pajeon is sometimes deep fried, but this recipe only requires limited amounts of canola oil for pan-frying.

In looking at the nutrition content of the recipes, the pajeon serves as a great source of potassium, Vitamin A and C, and folate. For the sauce, there was no low sodium soy sauce option when creating the recipe, so the nutrition facts label above may not be entirely accurate. Even so, because the recipe is meant to be divided into 8 parts, sodium consumption is still limited. Unfortunately, the nutrition facts labels do not reveal the polyphenol content of all the allium members incorporated into the recipe. But based on the research done in this paper, it is safe to conclude that there is an ample amount of diallyl disulfide available in the pajeon and dipping sauce.

Ancient civilizations and cultures have warned about garlic and other alliums, and it was not just used to ward off vampires. There is an Islamic myth where after Satan left the Garden of Eden, garlic arose in his left footprint and onion in the right (9). Those following the steps of the Buddha are warned to “refrain from eating [the] five pungent plants [onions, garlic, shallots, leeks and chives] of this world. If these five are eaten cooked, they increase one's sexual desire; if they are eaten raw, they increase one's anger” (10). Though there is no biological truth behind the diabolic dangers of consuming garlic and onion, one must watch for over consumption. One research study reported that raw garlic juice consumed by rats in a high dosage led to death by stomach injury. Another study suggested toxic liver injury with overconsumption (1).

Overall, the evidence of the benefits of consuming garlic and other alliums is overwhelming. The sharp pungent lingering smell of the pancake is a stark reminder of the presence of the compound allicin. Instead of just a single choice of topping, a combination of allium plants is used. With such a variety to choose from, consumers are not solely limited to garlic or onion. Allium plants add a lot of flavor, character, and aroma to dishes. However, research still lacks on the effects of cooking methods for garlic and dose-response. Therefore to fully understand the health benefits of this recipe, more future research on garlic and other alliums is still needed.



## WORKS CITED:

1. Corzo-Martinez, Marta, et al. "Biological properties of onions and garlic." *Trends in Food and Science Technology*, 2007. 18: 609-625.
2. "Phytochemicals." American Cancer Society, 2013.  
<<http://www.cancer.org/treatment/treatmentsandsideeffects/complementaryandalternativemedicine/herbsvitaminsandminerals/phytochemicals>>
3. Bianchini, F. and H. Vainio. "Allium vegetables and organosulfur compounds: do they help prevent cancer?" *Environmental Health Perspective*, 2001. 109(9): 893-902.
4. Block, Eric. *Garlic and other Alliums: The Lore and The Science*. Royal Society of Science, 2010.
5. Iciek, Malgorzata, et al. "Biological Properties of Garlic and Garlic-Derived Organosulfur Compounds." *Environmental and Molecular Mutagenesis*, 2009. 50: 247-265.
6. Gorinstein, S, et al. "The arteriosclerotic heart disease and protecting properties of garlic: contemporary data." *Molecular Nutrition Food Research*, 2007. 51: 1365-1381.
7. Yi, Lan and Qi Su. "Molecular mechanisms for the anti-cancer effects of diallyl disulfide." *Food and Chemical Toxicology*, 2013. 57: 362-370.
8. National Cancer Institute. "Garlic and Cancer Prevention." National Institute of Health, 2008.  
<<http://www.cancer.gov/cancertopics/factsheet/prevention/garlic-and-cancer-prevention>>
9. Pickering, David. *Cassell's Dictionary of Superstitions*. Cassell Reference, 2003.
10. "The Surangama Sutra." *Buddha Dharma Education Association Inc.*  
<[http://www.buddhanet.net/pdf\\_file/surangama.pdf](http://www.buddhanet.net/pdf_file/surangama.pdf)>