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EXPLORING THE HEALTH BENEFITS OF TEMPE: ENHANCING PHARMACOLOGICAL POTENTIAL THROUGH SOYBEAN COMBINATIONS

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ABSTRACT

Introduction: Tempe is one of the Indonesian traditional foods made through a fermentation process using soybeans as the primary ingredient. The fermentation process enhances the nutritional content by increasing the availability of polyunsaturated fats and protein while reducing anti-nutrients. Tempe contains bioactive compounds known as isoflavones, which function as antioxidants and protect against chronic diseases. Various in vivo studies have shown the health benefits of tempe, including improved immune system, gut microbiota, blood pressure, blood lipid profile, liver health, atherosclerosis prevention and cognitive function enhancement. Additionally, tempe shows potential as a chemotherapeutic agent for breast cancer. Tempe can be consumed directly or modified, combined or not, to get the value of tempe pharmacologically.

Methods: The review used national and international journals with keywords such as natural medicine, combination and tempe. The inclusion criteria were the impact of combined materials on the pharmacological value of tempe, with exclusion criteria related to non-pharmacological value and modification processes.

Result: Tempe contains isoflavones, such as daidzein, genistein and glycitein, which possess antioxidant properties. The fermentation process of tempe produces free isoflavones with higher antioxidant activity compared to conjugated isoflavones in soybeans. Additionally, there have been efforts to combine tempe with other substances in nanoparticle form to accelerate wound healing.

Conclusion: Several studies have explored the combination of tempe with other antioxidant sources like carrots, purple sweet potatoes, red rice, winged beans and black beans. This combination can enhance antioxidant activity and holds promise in addressing diabetes mellitus.

Keywords: Soybean, Antioxidants, Tempe, Isoflavones

INTRODUCTION

For centuries, traditional Indonesian food known as tempe has been an invaluable nutritional cornerstone recognized worldwide. Tempe, a fermentation product derived from soybeans, has gained popularity throughout the world because of its incredible health advantages and high nutritional content. Tempe, which has deep traditional origins in Indonesia, is more than just a dish; it's a cultural legacy that has assiduously merged into daily existence. It is well-known and appreciated that tempe is a superfood with exceptional nutritional value and a host of health advantages. Because it's inexpensive and nutrient-dense, tempe is a staple food protein source for the Indonesian population (Ahnan-Winarno *et al.*, 2021). According to Puteri et al. (2018), Tempe is renowned for its appealing flavour, texture and exceptional digestibility. Tempe is the result of solid-state fermentation of

soybeans with the help of a mould starter called Rhizopus spp. The manufacturing of tempe goes through several processing steps, such as soaking, dehulling, washing, boiling, draining, cooling, inoculating with a starter and incubating at room temperature (30 ± 2 °C) (Rahayu *et al.*, 2015). The broader community believes that consuming fermented soy-based foods can provide health benefits and help prevent chronic diseases. Fermented soy-based foods are known to be an excellent source of nutrition and health benefits due to their high protein content and phytonutrient content like isoflavones (Mukherjee *et al.*, 2015).

The fermentation procedure that is used to make tempe boosts its nutritious content. During the fermentation of soybeans, certain biochemical changes take place that increase the availability of polyunsaturated fats and protein while decreasing anti-nutrients such phytate, oxalate, trypsin inhibitor and antinutritive phenols. The ingestion of soy has been associated with an extensive array of health advantages, mostly because it contains bioactive substances known as isoflavones. It is possible that isoflavones function as antioxidants to shield cells from oxidative stress, lowering the risk of a number of chronic illnesses, including cancer, heart disease and neurological disorders (Liguori *et al.*, 2018).

Numerous in vivo investigations have endeavoured to determine possible health advantages associated with tempe intake. Rats given temper supplementation had an improvement in their immune system and a change in the makeup of their gut microbiota toward a healthy gut (Soka *et al.*, 2015). According to studies on tempe's antioxidant properties, it can lower blood pressure in hypertensive rats (Xiao, 2011), improve blood lipid profiles in rats fed a high-lipid diet (Mohd Yusof et al., 2013), shield mice from alcohol-induced liver damage (Ari-Agung et al., 2013), prevent atherosclerosis in rats when combined with carrot (Chan *et al.*, 2018) and improve cognitive functions in senescence-accelerated rats (Sanjukta & Rai, 2016). Furthermore, emphasized tempe's potential as a chemotherapeutic drug for breast cancer (Bintari & Nugraheni, 2017). Tempe itself or combined using others materials has been develop to increase the value of this product.

METHODOLOGY

This evaluation uses national and international journals as well as online search engines to find primary data sources on the internet. The relevant bibliography was manually searched in order to find more search sources via e-books or e-journals. Natural medications, combo, and tempe were the search terms used online. The impact of combination material on raising tempe's pharmacological value was the inclusion criterion in the article search. The articles that reviewed the exclusion criteria were non-pharmacological value and modification processes.

RESULTS

Various studies of show the benefits of tempe for health. So, various studies have also tried to combine tempe with other ingredients to increase public acceptance both in terms of taste and nutrition, as well as increasing its function as an active ingredient. One function that studied was antioxidant mechanism. Daidzein, genistein and glycitein are three types of isoflavones, which are bioactive substances with antioxidant properties (Xu *et al.*, 2015). The majority of isoflavones in soybeans are found conjugated with sugar molecules, called glucosides. The fermentation process produces free isoflavones, or aglycones, with greater bioavailability and antioxidant activities than isoflavone glucosides due to the hydrolysis of isoflavone glucosides by the enzyme beta-glucosidase secreted by R. oligosporus (Lee, 2005 ; Zaheer & Humayoun Akhtar, 2017).

It has been suggested that isoflavin's antioxidant activity can heal wounds. Basically, oxidative stress, or ROS and antioxidants must be in balance for the wound healing process to occur. ROS have also been identified as key players in the mediation of inflammation and cell signalling during wound healing; however, excessive oxidation may cause damage to cells by generating hydroxyl radicals in the presence of metals like iron and copper via the Fenton and Haber-Weiss reactions (Fitzmaurice *et al.*, 2011; Schafer & Werner, 2008). The goal of the delivery of wound healers in nanoparticle form was to activate several cellular and molecular mechanisms supporting the wound microenvironment (Cui et al., 2020). Combining silver and soybean in nanoparticles seems promising to speed up the

wound healing process. Soybeans in combination with nano gold also for delivery or imaging process. Soybean was source of carboxy, amino, thio, and hydroxy units within the protein frameworks that potentially used as ligand (Shukla *et al.*, 2008).

Soybeans that are already fermented or not also already combined with another source of antioxidants like carrot, purple sweet potato, red rice, winged bean and black bean. Antioxidant activity can be determined using DPPH radical scavenging activity and lowering ROS concentration in the sample. While increasing antioxidant activity was proven, another function can be approached like diabetes mellitus (DM). The auto-oxidation of glucose to produce free radicals is facilitated by hyperglycemia. Both macro and microvascular dysfunction are caused by the production of free radicals that exceed the capacity of the body's natural antioxidant defenses to scavenge against them. Increased endothelial cell apoptosis has also been linked to hyperglycemia-induced oxidative stress, both in vitro and in vivo. Numerous studies have demonstrated that diabetes mellitus (types 1 and 2) is associated with a decrease in antioxidant capacity and an increase in free radical production, which causes oxidative damage to cell components (Bajaj & Khan, 2012 ; Bashan *et al.*, 2009) .

Reducing radicals was impacting MDA levels in diabetes mellitus patients. ROS-oxidized lipid components can produce *Malondialdehyde* (MDA). Evaluation of MDA can be used as a marker of oxidative stress which can indirectly describe the effects of ROS because ROS compounds are reactive. One of the main pathogenic aspects of type 2 diabetes (T2DM) is insulin resistance, which can be exacerbated by ROS. ROS can also decrease the insulin response. Ironically, ROS produced by endomembrane and plasma membrane NADP(H) oxidases may also be necessary for regular intracellular signaling (Tiganis, 2011).

CONCLUSION

Tempe, a fermented product derived from soybeans, has gained popularity worldwide due to its remarkable health benefits and high nutritional content. Tempe, with its high antioxidant properties thanks to isoflavones like daidzein, genistein, and glycitein, has proven to be beneficial for health. The fermentation process of tempe produces free isoflavones with higher antioxidant activity than conjugated isoflavones in soybeans. Furthermore, tempe has been successfully combined with various other substances, including silver and gold nanoparticles, to accelerate wound healing. Research also indicates that combining tempe with other antioxidant sources such as carrots, purple sweet potatoes, red rice, winged beans, and black beans can enhance antioxidant activity and holds potential for addressing diabetes mellitus. Despite its significant potential, further research is needed to fully understand the benefits and applications of tempe in the context of health and medicine.

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Conflict of interest

There is no conflict to declare.

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Table 1. Tempe Combination and Its Pharmacological Effects

Added materials	Aims	Methods	Results	References
Silver nanoparticles	Tempe containing isoflavone as a wound healers and silver as an antibacterial	Lipid nanoparticles containing tempe and silver nanoparticle was added into gel base (Carbopol, TEA and PPG).	Lipid and silver nanoparticles of tempe extract can be formulated and the average particle size of lipid nanoparticle was 130.03 nm and silver nanoparticle was 94.76 nm. The average viscosity of lipid nanoparticles gel was 4.02 dPas and silver nanoparticles was 4.22 d.Pa.s. The average spreadability of lipid nanoparticles gel was 4.37 cm and silver nano particles is 4.05 cm. The average pH value of tempe extract lipid nanoparticles was 7.70 and silver nanoparticles was 7.33. this characteristicts was match as drug product to be deliver on skin as wound healers and antibacterial.	(Christania *et al.*, 2020)
Gold Nanoparticles	For molecular imaging and therapy	Soybeans in ionized water was added to NaAuCl4 and the mixture was stirred at 25 - C for 4 h. The color of the supernatant solution changed from light yellow to dark purple, indicating the formation of gold nanoparticles (Soy-AuNP-1).	Phytochemicals that contain functional groups such as carboxy, amino, thio, and hydroxy units within the protein frameworks, in combination with the presence of saccharides (sucrose and stachyose) embedded within soybeans, will provide synergistic chemical reduction power for the reduction of gold salts into their corresponding nanoparticles	(Shukla *et al.*, 2008)
Carrot (antioxidants beta-carotene, thiamine and riboflavin)	Increasing the total blood antioxidant capacity, decreases 8-Hydroxy-2-deoxyguanocine, and skin texture damage in rat irradiated with ultraviolet	Directly consumed in combination	This research concluded that supplementation with a combination of tempe with carrot for 2 gram/kg BW/day result in the maximal effect by increasing the total antioxidant capacity, decreasing the level of 8-hidroxi-2-deoxiguanosin and decreasing skin texture damage.	(Wahjuni & Gunawan, 2014)
Purple sweet potato (source of anthocyanin)	Improve antioxidant performance	Tempe and fresh purple sweet potato were sliced, dried in a 45°C oven, and then pulverized.	The tempe and purple sweet potato with ratio 1:1 showed the lowest ROS level and reduce MDA (malondialdehyde) levels if compared with the DM group.	(Putri *et al.*, 2020)
Ginger rhizome (*Zingiber officinale*	Increasing effect on insulin sensitivity	Tempe and Ginger rhizome was sliced, dried and	The effect of the combination of the tempe and red ginger has the biggest reduction in blood glucose	(Dewi *et al.*, 2020)

Roscoe) as source of gingerols and shogaols		ground using sieve mesh size 100 mm.	levels and the highest improvement of insulin sensitivity. This postulates that the combination of those has a synergistic effect to alleviate insulin sensitivity.	
Red rice (source of phenolic)	Increase antioxidant activity	Directly consumed in combination	The 2:1 of red rice: tempe powder mix beverage generate a total phenolic content and a DPPH radical scavenging activity as high as a single red rice powder beverage and 1.6-fold higher than that of a single tempe powder beverage.	(Agustinah & Yuandi, 2021)
Winged bean seeds, Black-eyed bean (source of phenolic acid, flavonoid and peptide)	Increased antioxidant activity	All materials were soaked in water, boiled, dried and inoculated with the starter then ferment at room temperature for 36 hours.	Formulation of soybean tempe with the addition of winged bean seeds as much as 50% obtained significantly higher protein content and antioxidant activity than control tempe	(Maitresya & Surya, 2023)