Chapter 3
Health Benefits Indonesian Fermented Food of *Tempeh Gembus* Upon National Readiness for Sustainable Development Goals Achievement

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ABSTRACT

Tempeh gembus is a traditional Indonesian prepared from solid tofu waste fermented by Rhizopus oligosporus. It contained some nutritional value and bioactives from fermentation, making tempeh gembus a functional food with variety of health benefits. Previous research had investigated functional properties of tempeh gembus, such as amidolytic, antimicrobial, and antioxidant, as well as proteolytic, fibrinolytic, fibrinogenolytic, and anti-inflammation, which were linked to a variety health benefits, including atherosclerosis, diabetes mellitus, hyperlipidaemia, obesity, metabolic syndrome, and osteopenia. Tempeh gembus is sometimes underestimated because it is prepared from tofu waste and is frequently consumed by low-income people due to its low cost. Tempeh gembus intake is also low due to a lack of knowledge about its health benefits. This article reviews the health benefits of tempeh gembus as one of Indonesia's local functional foods.

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INTRODUCTION

Producing *tempeh gembus* is one approach to achieving sustainable development goal number 2 of reducing hunger, achieving food security, and better nutrition because the main ingredients are formed from the pulp left over after making tofu. Indonesia has an estimated 84,000 tofu manufacturing units (Damanik et al., 2018) that produce roughly 1,024 million tonnes of solid waste and 20 million m^3/year of wastewaters having soybean as their main ingredient (Kurniasari et al., 2017). Adding *Rhizopus oligosporus* to tofu waste resulted in *tempeh gembus*, which was fermented for many days. *Tempeh gembus* includes protein, glucose, fiber, calcium, iron, fosfor, essential fatty acids, and bioactive compounds (Afifah et al., 2019a), even though the base material is waste-tofu.

The *tempeh gembus* fermenting process may lead to nutritional content and bioactive compound alteration. A previous study showed the variety of nutrition composition in soybean, tofu waste, and *tempeh gembus*. The carbohydrate, fat, and protein content in *tempeh gembus* are more easily digestible because the tempeh mold creates digestive enzymes. That study also indicated that fermentation may help to improve the fatty acids profile (Damanik et al., 2018).

Tempe gembus provides a variety of health benefits for humans due to its content, which is rich in nutrients and bioactives. Because *tempeh gembus* contains fibrinolytic enzymes, previous studies investigated its cardiovascular effects. Another study looked at the benefits of *tempeh gembus* for atherosclerosis, finding that *tempeh gembus* administration had a favorable association with homocysteine and malondialdehyde, though the correlation was not statistically significant. Another study revealed that *tempeh gembus* contains three times the fiber level of regular *tempeh*, which may be helpful to individuals who deal with obesity or diabetes. Another study found that *tempeh gembus* was positively connected with hyperlipidemia due to its ability to reduce cholesterol when consumed.

Because there is still limited information on *tempeh gembus*, it is necessary to write an article that explores *tempeh gembus* so that it can be useful to the community. This review article aims to investigate *tempeh gembus* nutritional and bioactive content, in addition to its health benefits.

Nutrition Content of *Tempeh Gembus*

Tempeh gembus is a soybean-based food produced from tofu waste. The nutritional value of *tempeh gembus* was investigated by Sulchan and Endang. Energy 65 kcal, total carbs 11.94 g, fiber 3.93 g, protein 3.41 g, fat 0.20 g, calcium 143 mg, iron 0.40 g, phosphorus 50 mg in 100 g *tempeh gembus*. Ruth, et al. investigated the nutritional composition of *tempeh gembus* as it changed from soybeans to tofu

wastes and finally to *tempeh gembus* (Damanik et al., 2018). Vitamins, minerals, fatty acids, and amino acids, were among the nutrients examined. *Tempeh gembus*, tofu waste, and soybeans, respectively, contain 4.80%, 5.40%, and 34.12% of amino acids. Soybeans (12.01%) had the lowest saturated fatty acid content, followed by tofu waste (12.41%) and *tempeh gembus* (12.55%). Monounsaturated fatty acid levels were also observed to follow a similar pattern (34.1 percent, 36.5 percent, and 36.7 percent respectively). Soybeans, on the other hand, contained more polyunsaturated fatty acids (43.6%) significantly than others, tofu waste (38.29%) and *tempeh gembus* (30.18%) (Damanik et al., 2018). Another study revealed that two isoflavones identified in *tempeh gembus* include genistein (57.1 g/g) and daidzein (33.1g/g) (Kurniasari et al., 2017).

Transforming *tempeh gembus* into a variety of dishes, like crackers, meatballs, cookies, and nuggets will rise its value. The nutritional content of dishes whose basic ingredients have been substituted using *tempeh gembus* has been the subject of several studies. Previous research explored *gembus* crackers in 6 different formulas by modifying the *tempeh gembus* and additive ratios. It revealed that gembus crackers had a high fiber content, ranging from 38.1 to 67.4 percent, fat content ranged from 11.8 to 16.8%, protein from 0.32 to 0.84 percent, and carbohydrate from 15.05 to 44.17 percent. Based on the sensory assessment and the triangle test, the panelists preferred the *gembus* cracker with additive, however, B3 was the best formulation suggested for consumption (Afifah et al., 2019a).

A study on the results of substituting *tempeh gembus* for the ingredients in meatballs was done by Arini et al. There are four formulas: 100 percent, 75 percent, 50 percent, and 25 percent of the meat can be replaced with *tempeh.* The best formula contains 8.03 percent protein, 351.9 mg/100 gr calcium, and 5.22 percent protein digestibility with a 25% *tempeh gembus* substitution. According to the study, one serving of *tempeh gembus* (78 mg) passes the nutritional label standard for the general category, which is 13% calories, 11% protein, and 25% calcium (Arini et al., 2019).

Research on replacing wheat flour with *tempeh gembus* flour on cookies has been done by Manullang et al (2020). Comparing cookie formulas with 0% and 25% substitutions of *tempeh gembus* flour, the cookie formula with 50% substitution had the lowest glycemic index (47.01%) and glycemic load (6.90%). Cookies made with that formula also had the highest levels of protein digestibility (20.27±0.43%), dietary fiber (24.61±0.41%), and starch digestibility (48.07±0.01%). Low GI and GL were achieved with the greater *tempeh gembus* flour substitution, whereas protein digestibility, dietary fiber, and starch digestibility were all high (Manullang et al., 2020).

Sinambela et al. (2020) likewise studied cookies made with *tempeh gembus* flour instead of wheat flour, but they focused on the nutritional differences between them. In five different formulas in this study, wheat flour will be substituted with *tempeh gembus* flour to varying degrees (0, 25, 50, 75, and 100%). Cookies made with 100 percent *tempeh gembus* flour were the best for high fiber, low fat, total energy, and carbohydrate, all of which were beneficial to obese adolescent girls while cookies containing 25% and 50% *tempeh gembus* flour were acceptable and favored.

Susanti et al used *tempeh gembus* instead of fish as the main ingredient of a nugget. This study uses 5 different substitutions for the *tempeh gembus*, including 0, 20, 60, 80, and 100%. The panelists' favored nugget formulation was the replacement treatment with 20% *tempeh gembus*. Considering the nutritious content, protein digestibility, acceptance, and compliance with all quality standards of nuggets, it was advised to substitute 60% and 20% of *tempeh gembus* in the formulas. Nuggets with 60 percent *tempeh gembus* substitution had 9.71 percent protein, 10.83 percent fat, 12.85 percent carbohydrate, 17.76 fiber, and 86.23 percent protein digestibility, whereas nuggets with 40 percent *tempeh gembus* substitution had 13.53 protein, 9.85 fat, 7.85 carbohydrates, 18.00 fiber, and 86.61 protein digestibility (Susanti et al., 2021).

Functional Properties

Tempeh gembus is produced using microorganisms as part of a fermentation process. The substance content of food can be impacted by the biological activity of the microorganisms that make it, including active substances with functional properties. Some of the functional properties included in *tempeh gembus*, such as amidolytic, antibacterial, and antioxidant activity, have been demonstrated in earlier studies.

Amidolytic Activities

The term "amidolytic" describes how a protease enzyme cleaves a peptide bond in a polypeptide or protein (Winter et al., 2020). The amidolytic method is a technique for measuring the concentration of functionally active antithrombin (Abildgaard et al., 2011). *Bacillus pumilus* 2.g was found in *tempeh gembus*, along with other microorganisms known to generate enzymes with antithrombin activity. To explore the properties of enzymes that produce fibrinolytic activity, a previous study isolated *B. pumilus* 2.g in gembus (Afifah et al., 2014a). The partly purified enzyme from *Bacillus pumilus* 2.g performed as expected in the fibrinogen hydrolysis assay. The study found that the chains α and β but not the chain γ of fibrinogen were degraded (Afifah et al., 2014b).

Antimicrobial Activity

Antimicrobials are a substance generated by an organism that kills or prevents another from growing (Purssell, 2020). As a result of the hydrolysis process, soybeans have different functional characteristics. For instance, proteolytic enzymes hydrolyze protein into peptides and amino acids that can also act as antibacterial agents (Ribotta et al., 2008). The potential of *tempeh gembus* hydrolyzate to fight bacteria was investigated by Noviana et al. *Bacillus subtilis*, *Escherichia coli*, *Streptococcus mutans*, and Staphylococcus aureus were used to investigate the antimicrobial properties of *tempeh gembus* hydrolysate bromelain enzyme (TGH BE). The highest inhibition zone against Staphylococcus aureus and *Streptococcus mutans* was found for TGH BE at 8,000 ppm in the exploratory results whereas the largest *Bacillus subtilis* inhibitory zone was seen at TGH BE at 5,000 ppm. TGH BE had no antibacterial activity against *Escherichia coli*. All treatments had no statistical differences in soluble protein or inhibitory zones against *Bacillus subtilis*, *Escherichia coli*, *Streptococcus mutans*, and *Staphylococcus aureus*. TGH BE had antibacterial properties against *Bacillus subtilis*, *Streptococcus mutans*, and *Staphylococcus aureus* (Noviana et al., 2018).

Antioxidant Activity

Antioxidant activity is the restriction or prevention of food oxidation (particularly of lipids and proteins) by limiting oxidative chain reactions (Guclu et al., 2020). Protein fragments known as bioactive peptides are inert within the parent protein's sequence but may exhibit physiological action once released (Sarmadi & Ismail, 2010; Singh et al., 2014). A fermented tofu waste called *tempeh gembus* has a high protein content and bioactive peptide components that may have antioxidant properties. Diana et al investigated the antioxidants in *tempeh gembus* after several food processing methods, including fresh, fried, steaming, and bromelain-added. Fresh *tempeh gembus* has an antioxidant activity of 48.07 percent, 0.05 percent genistein, and 0.07 percent daidzein. Antioxidant activity (39.72 percent), genistein (0.07 percent), and daidzein (0.09 percent) were all found in steamed samples. Antioxidant activity (61.00 percent), genistein (0.08 percent), and daidzein (0.10 percent) were all found in fried samples. *Tempeh gembus* with bromelain added had a total antioxidant activity of 62.04 percent, 0.07 percent daidzein, and 0.06 percent genistein. Bromelain added to *tempeh gembus* resulted in antioxidant activity profiles that were compared to fresh samples, steaming, and frying (Afifah et al., 2019b).

Another study looked at the antioxidant activity of *tempeh gembus* that released the bromelain enzyme to break up peptide bonds and release amino acids and bioactive peptides (Agustina et al., 2018). The four treatment groups had significant

differences in the *tempeh gembus* hydrolysate's soluble protein concentration and antioxidant activity (10.000 ppm, 8000 ppm, 5000 ppm, and 0 ppm). The ABTS test revealed that *tempeh gembus* hydrolysate has stronger antioxidant activity than the DPPH test. According to the ABTS test, the *tempeh gembus* hydrolysate's antioxidant activity improved as bromelain concentrations rose but not the DPPH test. As the concentration of bromelain enzyme rose, the hydrolysate of *tempeh gembus* contained less soluble protein (Agustina et al., 2018).

Health Benefits

The fermentation process used to make *tempeh gembus* yields fibrinolytic enzymes that can lower fibrinogen levels, one of the primary indicators of atherosclerosis. Hyperlipidemia can be treated with fiber and antioxidants from *tempeh gembus* by improving lipid profiles, such as lowering total cholesterol, LDL, and triglycerides and elevating HDL. Improving this lipid profile can prevent the oxidation of lipids, which raises the levels of cytokines linked to inflammation and oxidative stress such as MDA, homocysteine, and hs-CRP, all of which are indicators of atherosclerosis and obesity. *Tempeh gembus* has a low glycemic index, glycemic load, and high fiber content that can induce satiety while being low in calories, improving blood sugar and insulin profiles. This is advantageous for obese persons as it can help them cut back on consumption and calories. The metabolic syndrome is also prevented indirectly by *tempeh gembus* which improves lipid profiles, blood sugar, and obesity.

Atherosclerosis

Atherosclerosis is the result of hyperlipidemia and lipid oxidation which is characterized by the accumulation of lipids and fibrous elements that form plaque growth within the lumen of the arteries with a simultaneous loss of elasticity of the blood vessels (Head et al., 2017; Rafieian-Kopaei et al., 2014). Following the publishing of findings showing the deposition of fibrin and fibrin breakdown products in artery walls with atherosclerosis, a probable role for the fibrinolytic system in the development of atherosclerotic plaque was hypothesized. The fibrinolytic enzyme is a proteolytic enzyme that was initially discovered to be involved in the breakdown of fibrin and the maintenance of a patent lumen in the blood vessels (Jovin & Müller-Berghaus, 2004). The finding of fibrinolytic activity in enzymes produced by bacteria found in *tempeh gembus* motivated numerous researchers to do additional research by feeding *tempeh gembus* to experimental animals to examine how it affected atherosclerotic markers. Ratih et al. studied atherosclerotic markers such as blood malondialdehyde and homocysteine in rats given an atherogenic diet for four weeks and then given *tempeh gembus* for four weeks. This study found

that feeding rats 25 grams of *tempeh gembus* per kilogram of body weight reduced serum malondialdehyde and homocysteine levels, but not considerably (Kurniasari et al., 2017).

The protein hydrolyzate produced by the bromelain enzyme breaks down protein in *tempeh gembus,* resulting in an increase in antioxidants that prevent oxidative stress from damaging the endothelium, allowing it to optimally generate nitric oxide. Nitric oxide detoxifies homocysteine by attaching and converting it to a less harmful molecule, which also serves as a thrombosis inhibitor (Pushpakumar et al., 2014). The bromelain enzyme is also involved in increasing fibrin breakdown by enhancing plasminogen to plasmin conversion (Errasti et al., 2016).

The absence of detectable homocysteine in oxidized forms such as thiolactone in the ELISA Kit, which only tests total homocysteine comprised of thiol-homocysteine, disulfide homocysteine, and cysteine homocysteine, is one plausible mechanism explaining the insignificant decrease in homocysteine. Thiolactone is a reactive thioester that combines with Low Dense Lipoprotein (LDL) to generate foam cells, which are crucial in the development of atherosclerosis. The positive control group's atherogenic diet increased the incidence of hyperlipidemia, resulting in oxidized homocysteine-like thiolactone binding to LDL. LDL-Hcythiolactone is deposited as thioco and then converted to thioretinamide. The conversion of thioco to thioretinamide generates a lot of reactive oxygen species (ROS), which might lead to endothelial dysfunction. In smooth muscle cells, thioretinamide can cause proliferation and fibrosis (Yadav et al., 2006).

An atherogenic diet increase blood lipids and inflammation, which can elevate malondialdehyde (MDA) levels (Nisa et al., 2021). The antioxidant activity of the hydrolyzed protein made from *tempeh gembus* is quite strong (Agustina et al., 2018). antioxidants can limit lipid oxidation and thereby reduce MDA production. Genistein may also affect the reduction of MDA in the *tempeh gembus* group by activating the development of the enzyme superoxide dismutase and helping superoxide dismutase in its role of converting free radicals into neutral molecules, hence reducing MDA generation (Lee et al., 2004).

Blood levels of fibrinogen and high sensitivity C-Reactive Protein (hsCRP), two additional atherosclerosis markers, were also investigated. In this study, experimental animals fed an atherogenic diet were given different types of *tempeh gembus* (*tempeh gembus* containing bromelain, fresh *tempeh gembus*, and heated *tempeh gembus.* Among different types of *tempeh gembus*, administration of *tempeh gembus* with bromelain was the most effective for serum fibrinogen and serum hsCRP levels (Dewi et al., 2018).

HsCRP decreased in the intervention group, most likely due to the presence of isoflavones such as daidzein and genistein in *tempeh gembus*. Because of its anti-inflammatory characteristics, it lowers protein levels and the activity of protective

enzymes like phospholipase AZ (PLAZ), lipoxygenase (LOX), cyclooxygenase-2 (COX-2), and inducible nitric oxide synthases (iNOS), as well as suppressing the formation of pro-inflammatory contributors (Yu et al., 2016). Another potential explanation is that the presence of unsaturated fatty acids in *tempeh gembus* is linked to reduced levels of C-Reactive Protein (CRP), which is associated with the suppression of chronic inflammation (Muka et al., 2015). Linoleic acid and linolenic acid are polyunsaturated fatty acids that suppress the actions of cyclooxygenase, omega 6 desaturases, and omega-5 desaturase.

Tempeh gembus, which was given by the intervention group, is a fermented food that contains microorganisms such as bacteria. Diana et al discovered that bacteria living in *tempeh gembus* produce fibrinolytic enzymes. This fibrinolytic enzyme may have a key role in lowering fibrinogen levels in people who eat *tempeh gembus* (Afifah et al., 2014a; Afifah et al., 2014b). Fibrinolytic enzymes function as thrombolytics by activating plasminogen to convert it into plasmin, which can break down fibrin and hence remove thrombus (Afifah et al., 2014a). Another probable explanation is that the genistein in *gembus* inhibits the synthesis of thrombin and platelet activity, resulting in low fibrinogen levels (Afsaneh Bakhtiary et al., 2012).

Diabetes Mellitus

Diabetes is characterized by hyperglycemia, a metabolic condition brought on by deficits in insulin secretion, action, or both (American Diabetes Association, 2010). The most crucial aspect of diabetes mellitus is blood sugar control through meal regulation. According to previous studies, *tempeh gembus* has three times the fiber of *tempeh.* Other research has also revealed that *tempeh gembus* has a low glycemic index. *Tempeh gembus* is a functional food that diabetics can utilize as an alternative dietary ingredient because of these factors. Several gembus-based food processing modifications were created and tested for protein and starch digestion rates, dietary fiber, GI, and GL. Cookies made with 50 percent *tempeh gembus* flour have a GI of 47.01 percent, classifying them in the low GI group (<55) (Manullang et al., 2020).

Tempeh gembus has a beneficial effect on blood sugar and insulin, following studies by Isnawati et al and Nadia et al (Isnawati et al., 2020; Nadia et al., 2020). Isnawati et al. revealed in their research that the treatment group's fasting blood glucose levels were clinically lower by 4.5 mg/dl than the control group's, despite there being no statistically significant difference in fasting blood glucose levels between the two groups (Isnawati et al., 2020). Nadia et al studied insulin resistance following *tempeh gembus* intake. The study found that 28 days of daily administration of 150 grams of *tempeh gembus* reduced insulin resistance. The control group has a lower level of insulin resistance than the treatment group (Nadia et al., 2020).

Isoflavone-rich fiber diets are thought to lower insulin resistance (Charles et al., 2009; Chu et al., 2006). The high fiber content of *tempeh gembus* may contribute to the favorable impacts on blood sugar and insulin generated by its consumption. Fiber can promote glucose and insulin metabolism by lengthening the time food passes in the intestine. Fiber also has been demonstrated to improve the state of diabetes mellitus in several previous studies. Fiber intake for four weeks has been demonstrated to increase insulin secretion in overweight and non-diabetic patients in previous research (Bodinham et al., 2012). In other research, increasing fiber intake for a year has been shown to increase healthy individuals' glucagon-like peptide-1 (GLP-1) secretion (Wolever et al., 2008). Other research has found that people with Type 2 Diabetes Mellitus can reduce their HbA1c levels by eating a high-fiber diet (Mazidi et al., 2018). Fiber's high viscosity can also increase insulin sensitivity by decreasing macronutrient absorption (Clarkson, 2002). The ability of fiber to lower blood sugar levels is affected by efficient carbohydrate absorption, which causes a lower insulin response, allowing the pancreas to improve its performance because it produces insulin infrequently (Ahmed et al., 2010; Lu et al., 2013; Sedaghat et al., 2015). Furthermore, fiber can improve peripheral insulin sensitivity by causing the fermentation of fiber in the gut to produce short-chain fatty acids (Feder & Fonseca, 2017).

Hyperlipidemia

Hyperlipidemia is the medical term for an excess of fatty compounds in the blood. For the treatment and prevention of hyperlipidemia, fibers may exert a protective molecular mechanism (Nie & Luo, 2021). The high fiber content of tempeh indicates that it can be used to treat and prevent hyperlipidemia. Studies on the use of *tempeh gembus* to treat hyperlipidemia have been conducted. Hyperlipidemic women were given *tempeh gembus* for the research. In this study, there were three groups: the control group, which received no *tempeh gembus* but received nutritional education as a substitute, the group that received 103 g of *tempeh gembus* per day, and the other group received 206 g per day. These findings revealed that consuming 103 and 206 grams of *tempeh gembus* a day reduced LDL-C by 27.9% and 30.9 percent respectively (Afifah et al., 2020). The protein content of *tempeh gembus* may contribute to inhibiting cholesterol production, lowering bile acid and/or cholesterol absorption, and initiating the transcription process of LDL-C receptors, resulting in a drop in LDL-C in hyperlipidemic women using it (Greany et al., 2004). Furthermore, protein and fiber have been indicated to inhibit cholesterol absorption and enhance bile acid production in the intestine. Daidzein and genistein are phytoestrogens that boost LDL-C receptor activation (Sulchan, 2007).

Total cholesterol was also reduced by 17.7% and 19.8%. The fiber in *tempeh gembus* binds bile acids, reduces the intestinal absorption of cholesterol, and enhances fatty acid and cholesterol excretion from the liver during the creation of intraluminal micelles, allowing the liver to utilize cholesterol to produce new bile acids (Clarkson, 2002; van Bennekum et al., 2005). Fiber can also cause the gut microbiota to create short-chain fatty acids like butyrate, propionate, and acetate, which can impact lipid metabolism, synthesis of hepatic fatty acids, and bowel motility.

Contrary to theory, triglycerides increased by 2.3 and 3.1 percent, respectively. This could be attributed to serum triglyceride sensitivity and vulnerability to exogenous meal intake. Food intake has a significant impact on triglyceride levels. Food-derived triglycerides are completely absorbed, carried by chylomicrons, and circulated in the bloodstream. After 30 to 60 minutes of food ingestion, postprandial absorption of chylomicrons from the gastrointestinal tract can cause a 3- to 10-hour increase in blood triglycerides (Clarkson, 2002).

This study discovered a tiny but significant rise in HDL-C of 3.91 percent and 8.79 percent, respectively because physical activity has a bigger influence than food intake and the effect of fiber on boosting HDL-C levels is still unclear. Several kinds of research that investigated the impact of fiber on HDL-C found that it had a minor, inconsistent, or non-existent effect (Thompson & Rader, 2001).

Obesity

Obesity is a multifactorial, complex metabolic illness that is becoming recognized as a major primary health problem that lowers the quality of life due to its complications. There were studies to support the idea that inflammation and oxidative stress play a crucial role in the relationship between obesity and the complications it causes (Manna & Jain, 2015). *Tempeh gembus* is high in antioxidants, fiber, and unsaturated fatty acids, all of that can assist in reducing inflammation. Wati et al and Nadia et al were inspired to investigate the effects in hsCRP, HDL, and triglycerides caused by *tempeh gembus*. For 28 days, obese women were given up to 150g of *tempeh gembus* per day (Nadia et al., 2020; Wati et al., 2020). The findings of this study show that having *tempeh gembus* reduces hsCRP, increases HDL, and lowers triglycerides. This is consistent with recent research, which shows that meals based on soy can cut high sensitivity C-Reactive Protein levels by 25%. It is possible to detect the anti-inflammatory action in the reduction in C-Reactive Protein levels (Kim et al., 2014). Increased CRP can be protected by consuming more fiber. Previous research has found that lowering fiber intake promotes pro-inflammatory cytokines, particularly IL-6 while increasing IL-6 increases CRP levels. Fiber can also lower cholesterol levels in the body, resulting in decreased CRP levels and increased anti-inflammatory

effects. Furthermore, fiber can limit fat oxidation, lowering inflammation and hence CRP (Ma et al., 2006).

Isoflavones, a kind of antioxidant can also be found in *tempeh gembus* (Afifah et al., 2019b). Isoflavone inhibits NF-κB's transcriptional mechanism, whereas NF-KB activates the transcription of pro-inflammatory cytokines and chemokines genes, along with cyclooxygenase and inducible nitric oxide synthase. Pro-inflammatory enzymes such as cyclooxygenase 2, phospholipase A2, inducible nitric oxide, and lipoxygenase, are also inhibited by isoflavones (Yu et al., 2016). *Tempeh gembus* antioxidant action is probably derived from bioactive amino acids/peptides in addition to isoflavones. Tryptophan, histidine, lysine, methionine, histidine, and cysteine are among the amino acids found in *tempeh gembus.* Antioxidant activity in soybean gembus was measured using the ABTS method and found to be 63.14±1.16% (Agustina et al., 2018).

According to previous research, giving *tempeh gembus* for 28 days can prevent weight gain in all treatment groups since the fiber in *tempeh gembus* might enhance satiety, lowering energy intake indirectly (Clarkson, 2002; Wati et al., 2020). It can also help in the elimination of cholesterol and bile acids through the feces, avoiding the return of bile acids to the liver (Jesch & Carr, 2017). The liver's ability to convert cholesterol to bile acids is increased when bile acids are produced at a lower level, which raises high-density lipoprotein (HDL) levels (Staels & Fonseca, 2009). The elevation in HDL levels in the treatment group may have been caused by the presence of flavonoids in *tempeh gembus*, in addition to fiber. Flavonoids can raise Apolipoprotein A-1 concentration in the body. In HDL tissues, apolipoprotein A-1 functions as a ligand for the lipoprotein receptor or even an enzyme cofactor for LCAT. HDL is projected to rise as Apolipoprotein A-1 levels rise (Groper et al., 2009). Several reasons contribute to increased HDL levels that do not reach ideal levels in that study, and one is exercise (Whitney & Rolfes, 2015). Regular exercise can improve Apolipoprotein A-1's ability to remove cholesterol from blood vessel walls as an HDL receptor (Kingwell & Chapman, 2013).

Because CYP51 is the first sterol intermediate in the cholesterol biosynthetic pathway, it is an important gene in cholesterol biosynthesis (Rozman et al., 2005). Previous research has found that okara consumption causes fatty acid synthetase genes to be downregulated and CYP7A1 genes to be upregulated, both of which are beneficial to obesity prevention (Matsumoto et al., 2014). CYP7A1 is a gene that controls the biosynthesis of bile acids. The fiber in *tempeh gembus* may help to accelerate fecal bile acid excretion and promote cholesterol to bile acid conversion, lowering plasma cholesterol levels. A high-fiber diet has been demonstrated to affect the expression of liver genes involved in cholesterol synthesis, such as CYP51, and that the effect of raising bile acids is most likely what causes the reduction in cholesterol (Chan & Heng, 2008).

Metabolic Syndrome

Metabolic syndrome is a risk factor that increases the risk of heart disease and other health problems, such as obesity. Inhibiting the oxidation of other molecules, antioxidants are reducing agents that can be utilized to prevent as well as treat the health issues associated with atherosclerosis and multiple sclerosis (Martins Gregório et al., 2016). According to a previous study, *tempeh gembus* is a beneficial diet rich in flavonoids, fiber, amino acids, and polyunsaturated fatty acids. These contents suggest that it can benefit in the reduction of metabolic syndrome risk via inflammatory pathways. This led Ikawati et colleagues to study the effect of *tempeh gembus* on rats with metabolic syndrome (Sulistyaningsih et al., 2020). *Tempe gembus* that was administered to metabolic syndrome rats for 28 days can significantly affect hsCRP through various processes, including the polyunsaturated fatty acid content in *tempeh gembus*, which may play a role in controlling hsCRP concentrations and other inflammatory indicators (Shen & Ordovas, 2009; Sulistyaningsih et al., 2020). The fiber in *tempeh gembus* also helps to reduce hsCRP levels by reducing lipid oxidation, balancing intestinal flora, and suppressing hyperglycemia (King, 2005; North et al., 2009).

That study also showed that giving rats with metabolic syndrome *tempeh gembus* increase adiponectin levels (Sulistyaningsih et al., 2020). Interleukin-6, TNF-a expression, hsCRP, and nitric oxide synthesis can all be inhibited by adiponectin, which is a cardioprotective cytokine (Devaraj et al., 2003, 2008). Fiber, unsaturated fatty acids, and isoflavones found in *tempeh gembus* can all influence adiponectin levels (Silva et al., 2011; Vajihe Izadi & Leila Azadbakht, 2015).

SOLUTIONS AND RECOMMENDATIONS

Tempeh gembus is a different approach to reduce waste for tofu manufacture. *Tempeh gembus* can also be used as an alternative source of protein and fiber to meet the nutritional need.

Future Research Directions

Future studies are required to determine the factors that influence the production of *tempeh gembus* in various nations, particularly those with varying climatic conditions, in order to develop this healthy alternate diet solution.

CONCLUSION

Many Indonesian traditional foods are still undiscovered in terms of their health advantages. One of Indonesia's traditional foods, *tempeh gembus*, is fermented and seems to have several functional properties like amidolytic, antimicrobial, and antioxidant activity thus *tempeh gembus* may have health advantages to aid with atherosclerosis, diabetes mellitus, hyperlipidemia, obesity, and metabolic syndrome. This article reviews the findings of different studies on *tempeh gembus* and how it affects human health.

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KEY TERMS AND DEFINITIONS

Fermentation: A process that transform complex compound in soybean dreg by Rhizopus spp. mold activity into digestible compounds.

Fibrinolytic: An activity that breakdown fibrin in blood clots.

Isoflavone: A bioactive compound with antioxidant and estrogenic activities in the body.

Peptide: A short chain of amino acids that linked by peptide bonds and it can result from protein degradation.

Sustainable Development Goals (SDGs): Actions to end poverty, safeguard the environment, and guarantee that by the year 2030 everyone lives in peace and prosperity. There are 17 SDGs that are integerated; 1. No poverty; 2. Zero hunger; 3. Good health and well-being; 4. Quality education; 5. Gender equality; 6. Clean water and sanitation; 7. Afforfable and clean energy; 8. Decent work and economic growth; 9. Industry, innovation and infrastructure; 10. Reduced inequalities; 11. Sustainable cities and communities; 12. Responsible consumption and production; 13. Climate action; 14. Life below water; 15. Life on land; 16. Peace, justice and strong institution; 17. Partnerships for goals.

***Tempeh gembus*:** A food made by tempeh mold *Rhizopus spp.* from tofu waste.

Tofu waste: Soybean dreg from producing tofu.