jffn Journal of Functional Food and Nutraceutical

NON-SOY LEGUMES AS ALTERNATIVE RAW INGREDIENT FOR *TEMPE* PRODUCTION IN INDONESIA WITH ADDITIONAL HEALTH BENEFITS: A REVIEW

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ABSTRACT

The availability of legumes in Indonesia is abundant. Many of them show great potential as an alternative ingredient to suppress the deficiency of nutrient intake. However, the utilization needs to be improved. The aim of this review is to evaluate the potential of selected non-soy legumes which are jack bean, mung bean, red kidney bean, and cowpea based on some consideration such as productivity and their potential to be used as raw ingredient for *tempe* production related to the nutrient content and functional properties. Despite of the high production of non-soy legumes, the utilization is still considerably low. Several researches stated that non-soy legume shows a great nutrient profile and good functionalities after being processed into *tempe*. Nutrient content of jack bean, mung bean, red kidney bean, and cowpea were improved due to the removal of antinutrients by the processes involved in *tempe* production. It shows a similarity and comparability to nutrient content of soybean *tempe* and even shows better functionality.

Keywords: alternative; health benefit; legumes; tempe

ABSTRAK

Ketersediaan kacang-kacangan (legumes) di Indonesia sangat melimpah. Banyak diantaranya menunjukkan potensi sebagai bahan alternatif dalam pemenuhan kebutuah gizi, namun demikian pemanfaatannya masih belum optimal. Kajian ini bertujuan untuk mengevaluasi potensi kacang-kacangan (legumes) non-kedelai, yaitu kacang koro, kacang hijau, kacang merah, dan kacang tunggak berdasarkan produktivitas dan potensinya sebagai bahan baku pembuatan tempe, dalam kaitannya dengan kandungan nutrisi dan sifat fungsional untuk kesehatan. Meskipun produksi kacang-kacangan non-kedelai ini cukup tinggi, pemanfaatannya terbilang masih sangat rendah. Beberapa penelitian menunjukkan bahwa kacang-kacangan non-kedelai ini menunjukkan profil gizi dan sifat fungsional yang baik setelah diolah menjadi tempe. Kandungan gizi keempat kacang non-kedelai ini menjagi lebih baik karena hilangnya zat anti gizi selama proses produksi tempe. Tempe yang terbuat dari keempat kacang non-kedelai ini memiliki kandungan gizi setingkat dengan tempe kedelai dan menunjukkan manfaat untuk kesehatan.

Kata kunci: bahan baku alternative; manfaat kesehatan; kacang-kacangan leguminosa; tempe

Article Information

Article Type: Research Reviews
Journal Type: Open Access
Volume: 3 Issue 1

Manuscript ID
V3n1791-1

Received Date
11 July 2021

Accepted Date
28 August 2021

Published Date
31 August 2021

DOI: 10.33555/jffn.v3i1.73

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Citation:
Rahmawati, D., Gunawan-Puteri, M.D.P.T., Santosa, E. 2021. Non-soy legumes as alternative raw ingredient for *tempe* production in Indonesia with additional health benefits: a review. J. Functional Food & Nutraceutical, 3(1), pp.23-38

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INTRODUCTION

Tempe is one of Indonesian fermented food that was usually made from soybean (*Glycine max (L.) Merr.*). The process of making *tempe* is much influenced by the activity of certain microorganisms, such as *Rhizopus oligosporus, R. oryzae, R. stolonifer, R. arrhizus, R. formosaensis, Mucor* spp, yeast, lactic acid bacteria, and different gram-negative bacteria. However, the main fungus of *tempe* production is *R. oligosporus* (Sharma and Sarbhoy, 1984).

According to Badan Pusat Statistik (2019), people in Indonesia consumed an average of 0.146 kg of *tempe* per capita per week in 2018. This amount of consumption is increasing compared to previous years while on the other hand the productivity of soybean of each province in Indonesia decreased by 4.62% from 2017 to 2018 (Statistik, 2019). Additionally, Indonesia imported as much as 2.52 million tons of soybean from America in the same year (Statistik, 2019). The national dependency of imported soybean influenced *tempe* producers to suffer due to the fluctuated currency. Therefore, other source of raw material is needed to reduce this problem.

Soybean has become the only legume which is being utilized massively as ingredient for *tempe* compared to other legumes. The utilization of soybean is mainly for *tempe* production and its derivatives. While on the other hand other legumes also show great potential to be utilized as *tempe* ingredients.

Tempe from other raw materials has been known by Indonesian since mid-1970s and it is reported in Shurtleff & Aoyagi (2007). Production of non-soy legumes as *tempe* ingredient is expected to increase demand of non-soy legumes. Based on previous study, it was shown the potency of non-soy legumes as *tempe* ingredient as *tempe* production contribute to the improvement of nutritional content and functionality. Therefore, non-soy legumes in Indonesia have a promising potential to be utilized (Belinda, A, 2015).

There are many types of legumes that can easily be cultivated in Indonesia. The cultivation of non-soy legumes is relatively easy, and they have commonly been used in Indonesia. In some research, it has been shown that their physical properties as well as the nutrient profile show a great potential to be utilized as raw ingredient for *tempe* production. (Pupitojati, Indrati, Cahyanto, & Marsono, 2019; Dewi, 2014; Grace, 2017; Radiaty & Sumarto, 2016). Non-soy legumes such as mung bean, cowpea, jack bean, and red kidney bean have shown their potential in some aspects.

Cowpea is potential for its sustainability and nutrient content. According to (Utomo & Antarlina, 1998) the cultivation of cowpea could take place in a marginal area which may not have such a good drainage and nutrients-rich soil. In some regions in Asia and Africa, cowpea is utilized to prevent stunting and improve protein intake. Red kidney bean is famously known for their role in improving nutrients intake (Astawan, 2009). Utilization of plant-based food has been reported to be able in maximizing protein intake and decreasing health issues (Shehzad, et al., 2015). Several market researches showed that the demand and awareness of foods with certain functionality and health benefit are increased. Mung bean and jack bean utilization may also be promising in the functional food industry. Mung bean contains folate which may help to prevent the defect of neural tube (Czeizel, Dudás, Vereczkey, & Bánhidy, 2013). While jack bean, an underutilized legume was found to contain l-canavanine which has potential to inhibit cancer cells in pancreas (Swaffar, Ang, Desai, & Rosenthal, 1994).

Regardless of the potential of non-soy legumes, the current consumption is still considerably low. Utilization of non-soy legumes as a raw ingredient of *tempe* could be a promising approach in improving the consumption. This study will discuss Indonesian popular non-soy legumes, namely mungbean, red kidney bean, cowpea, and jack bean, their potentials for its utilization as raw ingredient in *tempe* production with additional benefits. Scope of the discussion include of physical, chemical, nutritional content, and health benefit of the legumes in comparison to soy and as ingredient in *tempe* processing. This study will also discuss the different in production process of each legume to become tempe.

Variation of *tempe* in Indonesia

As the demand of soybean increases, the prevalence of other local legumes is hindered, while the production of soybean in each city in Indonesia is still considered to be not adequate (Statistik, 2019). The import of soybean also costs a lot more, therefore many researches have been conducted related to the innovation of making *tempe* with different non-soy legumes *as* raw ingredients.

Traditionally and due to scientific curiosity, there have been a lot of variations of *tempe* made of various raw ingredients. In Indonesia, many types of legumes can be found in each island. And there has been a lot of involvement of many legumes to be used as raw ingredient to produce tempe (Table 1). Some of the variations that have been consumed in Indonesia are *tempe semangit*, *tempe kacang merah*, *tempe kacang hijau* (Jateng), *tempe bongkrek*, *tempe enjes tempe kedelai* (Malang), *Oncom merah* and *hitam* (West Java) (Suprapti, 1996).

Table 1. Raw materials from Indonesia used for *tempe* fermentation

Raw Material	Name of *Tempe*	Origin
Soybean *(Glycine max)*	*T. Kedelai*	Malang, East Java
Mung bean *(Vigna radiata)*	*T. Kacang hijau*	Yogyakarta, Central Java
Lamtoro *(Leucaena)*	*T. Lamtoro*	Wonosari, Central Java
Pigeon Pea *(Cajarus cajan)*	*T. Kacang Iris*	Lombok, East Bali
Lablab *(Lablab purpureus)*	*T. Koro Wedus*	ND
Jack bean *(Canavalla ensiformis)*	*T. Koro Pedang*	ND
Cowpea *(Vigna unguiculate)*	*ND*	ND
Kidney bean *(Phaseolus vulgaris)*	*ND*	ND
Winged bean *(Psophocarpus tetragonolobus)*	*T. Kecipir*	Papua New Guinea
Coconut pressed cake	*T. Bongkrek*	Banyumas, East Java
Velvet bean *(Mucuna pruriens)*	*T. Koro Benguk*	Cental & East Java

ND: Not Defined
Source: (Shurtleff & Aoyagi, 2007)

Existence of the *tempe* variats based on the raw ingredient showed potential for *tempe* development using non-soy legumes. Cowpea is suitable as a raw ingredient for *tempe* production (Haliza, Purwani, & Thahir, 2007). Cowpea seeds in Indonesia are mostly utilized as an additional vegetable cooked with jack fruit stew and vegetables with coconut soup or mixed with other ingredients for porridge, *bakpia*, and rice cake. Through fermentation process, cowpea is gaining some attributes that give it the potential to be utilized as an ingredient for *tempe* (Haliza, Purwani, & Thahir, 2007). According to Wardiah, Samingan, & Putri (2016), cowpea *tempe* contains p-coumaric acid and ferulic acid which is expected to be the most powerful antioxidant. Ferulic acid contained in cowpea *tempe* can suppress blood pressure and glucose level in the blood. Red kidney bean is one of various commodity of local legumes that is well known in Indonesia. Fermentation is able to increase the nutrient and digestibility profile of red kidney beans (Maryam, 2016). In other hand, mung bean also found to have greater soluble protein. Another bean such as jack bean, fermentation resulted a bioactive compound with high ACE inhibitory activity after fermentation by *Rhizophus sp.* molds (Pupitojati, Indrati, Cahyanto, & Marsono, 2019).

Characteristic and potency of non-soy legumes as ingredient for *tempe*

Classification and physical characteristic

Based on Table 2, all legumes are having the same division and family when compared to soybean. Therefore, it can be said that cowpea, mung bean, red kidney, and jack bean have the possibility to be raw ingredients for *tempe* although each of those non-soy legumes have different physical characteristic.

Table 2. Classification of legume

Legumes	Classification	
	Genus	Species
Soybean	*Glycine*	*Glycine max L.*
Cowpea	*Vigna*	*Vigna unguiculata*
Mung bean	*Vigna*	*Vigna radiate (L.) R.*
Red kidney	*Phaseolus L.*	*Phaseolus vulgaris L.*
Jack bean	*Canavalia*	*Canavalia ensiformis*

Each legume has difference in size, color, peels, and weight. Size of seeds influences the fermentation process. Hence, the quality of *tempe* will also be determined by the seeds size. As it can be seen in Table 3 and Figure. 1, cowpea has a similar weight to soybean. The weight of 50 cowpea seeds is 7.0 grams compared to that of soybean which is 8.0 grams. The similarity of the weights seemed to be the advantage of cowpea to be used for *tempe* ingredient based on size. This is also supported by Haliza, Purwani, & Thahir, (2007) that the seed size of cowpea can be used as potential *tempe* ingredient.

Figure 1. Peeled legumes. A. Jack bean, B. Red kidney bean, C. Cowpea, D. Soybean, E. Mungbean.

The physical changes of each non-soy legumes were also observed. The observation was done by applying some processes involved in *tempe* production such as soaking, dehulling, and boiling since the observation aimed to know the ability of each non-soy legumes to absorb water during *tempe* processing and further, influence the ability of each of these non-soy legumes to be dehulled that might also be different due to the rigidity difference. Due to the rigid texture of red kidney bean, cowpea, and jack bean, longer soaking was required in order to be processed further based on *tempe* production process. Therefore they were soaked for 24 hours instead of 12 hours. It appears that all legumes experienced increases in weight after 12 or 24 h of soaking. Shown in Table 3.

The time variation of heat treatment of the legumes, resulted in different antinutritional content of each legume (Popova & Mihaylova, 2019). When introduced to heat treatment the antinutrient content in mung bean and red kidney bean are faster to be removed, therefore it requires only 15 minutes to be softened and able to be processed further. The ability to be softened is an important factor for *tempe* making, because it influences the effectivity of fermentation by the molds. The softer the legumes, the more effective the fermentation. This proves that mung bean and red kidney bean are more potential in term of texture. Another factor that influences heat treatment time of each non-soy legumes is carbohydrate content. It is known that mung bean and red kidney has the highest carbohydrate content. Higher carbohydrate content will result in faster heat treatment process. When introduced to heat treatment, the raw tissue of seeds will be broken, and this might allow the starch to be ruptured and dispersed causing leaching of amylose.

Table 3. Physical characteristics of each legume based on *tempe* processing. **A.** Weight of seeds in different soaking treatment. **B.** Weight of seeds in different heat treatment

A

Type of Seeds	Initial	Weight of seeds (g)			
		12 h		24 h	
		Weight of 50 seeds (g)	Expansion percentage (%)	Weight (g)	Expansion percentage (%)
Soybean	8.0	19.0	137.5	-	-
Mung bean	3.0	8.0	166.7	-	-
Red kidney bean	22.0	43.0	95.5	45.0	104.5
Cowpea	7.0	14.0	100.0	16.0	128.6
Jack bean	74.0	112.0	51.4	117.0	58.1

B

Type of Seeds	Initial	Weight after heat treatment			
		15 min		30 min	
		Weight of 50 seeds (g)	Expansion percentage (%)	Weight (g)	Expansion percentage (%)
Soybean	8.0	16.0	100.0	15.0	87.5
Mung bean	3.0	11.0	266.7	-	-
Red kidney bean	22.0	37.0	68.2	-	-
Cowpea	7.0	13.0	85.7	13.0	85.7
Jack bean	74.0	121.0	63.5	118.0	59.5

Nutrient content

The utilization of non-soy legumes is still considerate as low. While they are also showing great potential from nutrient profile. Referring to **Table 4**. It was shown that the protein content of each non-soy legumes is lower than compared to soybean. However, when processed into *tempe*, could improve protein content of each legume (Radiaty & Sumarto, 2016).

Table 4. Nutrient content of each legume per 100 g

Nutrients	Legumes				
	Soybean	Cowpea	Mung bean	Red kidney	Jack bean
Water	8.54 g	11.05 g	9.05 g	11.75 g	15.5 g
Protein	36.49 g	23.85 g	23.86 g	22.53 g	27.6 g
Fat	19.94 g	2.07 g	1.15 g	1.06 g	3.9 g
Carbohydrates	30.16 g	59.64 g	62.62 g	61.29 g	56.9 g
Total soluble sugar	ND	ND	ND	ND	4.20 g *
Fibre	9.3 g	10.7 g	16.3 g	15.2 g	8.0 g
Calcium	277 mg	85 mg	132 mg	83 mg	247 mg *
Phosphorus	585 mg	438 mg	367 mg	406 mg	338 mg *
Iron	15.7 mg	9.95 mg	6.74 mg	6.69 mg	7 mg
Potassium	1797 mg	1375 mg	1246 mg	1359 mg	141 mg

Source: (Gebhardt & Thomas, 2002) (Rodrigues & Torne, 1992)*
ND: Not defined

Mung bean

Proximate analysis data was collected from several researches of *tempe* made from non-soy legumes (Table 5). When compared to the Standard Nasional Indonesia (SNI) of *tempe* by BSN, (2015) protein content of mung bean *tempe* is lower than the required amount. This result is similar to a research by Angelina, et al., (2016) who reported that the protein in mung bean *tempe* was only 11.73 % at the highest and met the required *tempe* standard by SNI 3144:2009 for *tempe*. This difference may be influenced by the different in cultivars.

Despite the lower protein content of mung bean, the protein digestibility, however, was reported to be better than soybean *tempe*. This is supported by the findings that the protein digestibility and soluble amino acid in mung bean *tempe* was found to be better than in soy *tempe* and remain the same after the production was upscaled industrially (Belinda, 2015; Angelina, 2016; Grace, 2017)

Cowpea

The initial carbohydrates content in cowpea was shown to be 59.64 g/100 g in Table 5. However, after fermentation the carbohydrate content was decreased to 18.97 % (Table 5). This might be due to enzymatic degradation of carbohydrate by lactic acid and molds fermentation. This is supported by (Madodé, et al., 2013) that galacto-oligosaccharides (GOS) was reduced effectively after fermentation followed by soaking and boiling.

Table 5. Proximate analysis of mung bean, cowpea, jack bean, red kidney *tempe*

Tempe	Protein Content (%wb)	Fat (%wb)	Carbohydrate (%wb)	Moisture (%wb)	Ash content (%wb)
Soybean	17.93	7.82	49.38	65.65	1.28
Mung bean	14.96	0.2	20.27	64.32	0.25
Cowpea	16.04	0.67	18.97	63.47	0.83
Jackbean	28.29	0.68	22.83	67.02	0.18
Red kidney	23.75	0.11	34.19	41.71	0.24
SNI (Soybean *Tempe*)	Min. 16	-	-	Max. 65	Max 1.5

*wb: wet basis; *)remark of result that is not in wet basis and with unknown units.
Source: (Iswandari, 2006; Dewi, 2014; Widaningrum, Sukasih, & P, 2015; Wicaksono, 2014)

The protein content in cowpea after *tempe* fermentation was shown in Table 6. The protein content of cowpea *tempe* was 16.04 % and it was lower when compared to *tempe* standard (BSN, 2015). The SNI for *tempe* is ideally 16 (%wb) meaning that the protein content of cowpea *tempe* by Dewi, (2014) has already met the standard. Fermentation time also gives an impact to the protein content. It was increased gradually the longer the fermentation. The release of amino group from protein and the release of the nitrogen from vitamin B12 was predicted to be the reason (Dewi, 2014).

Jack bean

The proximate analysis of whole jack bean *tempe* can be seen in **Table 6**. The protein content was 28.29% and was lower than the raw form which was 34% (Widaningrum, Sukasih, & P, 2015). The decrease in protein content is due to the hydrolysis of protein into a simpler amino acid (Belinda, 2015). This is similar to the findings during fermentation of jack bean for which it was reported that there was a significant increase in soluble protein that might be caused by the activity of proteolytic enzyme of Rhizopus sp. (Widaningrum, Sukasih, & P, 2015). The nutrient content from combination of 25% jack bean mixed with 75% of jack bean was known to be good and meet the SNI 3144:2009 for *tempe* except for fat content. The fat was lower than the standard because of the 25% combination of jack bean. (Kusumawardhani, 2015).

Regardless of the excellent nutrient content, the consumption of jack bean *tempe* is still low due to its low sensory acceptance (Kusumawardhani, 2015). This could be improved by turning jack bean *tempe* into flour. The shelf-life may be extended while at the same time the application might be broadened.

Red kidney bean

Red kidney bean was reported to be a good ingredient for *tempe* (Srapinkornburee, Tassanaudom, & Nipornram, 2009). The whole *tempe* processing was reported to increase the content of protein, soluble protein, and amino acid. In contrast, the ash content, carbohydrate, oligosaccharide, fat, and antitrypsin was decreased (Karisma, 2014). Modification of the seeds surface give a difference in nutrient profile of the resulted *tempe*. The reduction of size was found to give influence on the chemical characteristic of red kidney *tempe* such as soluble protein. A size of 10 mesh grits was reported to improve the protein content and lower the fat content (Wicaksono, 2014).

Functional Properties

In Table 6 the functional properties of the different non-soy legumes are being displayed as well as with which method they have been determined. The result will be discussed in the following paragraphs.

In general, every legume has functional properties. Many researches have shown their roles in providing bioactive compound. However, their bioavailability is depending on the antinutritional components that might give a disruption on the functional properties of legumes.

Mung bean

Phenolic compound contained in mung bean seeds is considered to be high with the amount of 0.62 to 1.08 g/100 g of dry matter (Anwar, Latif, Przybylski, Sultana, & M, 2007). Vitexin and isovitexin (Figure 2) are known to be the most common flavonoids found in the seeds coat as they give a 96.2% contribution to the total of antioxidant activity contained in mung bean seeds (Cao, et al., 2011). However, due to dehulling process, in *tempe* fermentation, it is expected that isovitexin and vitexin amount was also reduced in significant amount.

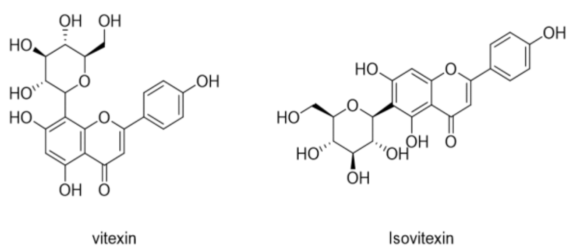

Figure 2. Chemical structure of vitexin (left) and isovitexin (right) in mung bean

According to Belinda (2015), *tempe* fermentation increased total phenolic compound of mung bean from 238.24 mg GAE/100g dry base on its original seed into 404.89 mg GAE/100 g dry base. And upscaled *tempe* production seemed to benefit the antioxidant activity, as Grace (2017) showed that DPPH radical scavenging activity of 20kg-batch produced *tempe* (86.91%) was higher compared to laboratory scale (5 kg) and small scale (500 grams). Looking up to the changes, mold fermentation seemed to recover the antioxidant of mung bean. This is supported by the findings from Limón, et al., (2015) who found that solid state fermentation of beans gave an improvement in antioxidant activity. Antioxidant activity of mung bean *tempe* was expected to be influenced by some compounds such as beta-carotene, phenolics, and protein (Belinda, 2015). However, further analysis showed that there is no correlation of beta-carotene to the antioxidant activity of mung bean *tempe* while phenolic content and protein have correlation to it. A finding by Angelina (2016); Grace (2017) even found that beta-carotene was not detected while at the same time they found a higher antioxidant activity in mung bean *tempe*.

Cowpea

In cowpea, polyphenols are found to be the major bioactive compound which is mostly contained in the husk of the seeds and ranging from 63.14 ± 4.45 mg gallic acid equivalents (GAE) /100 g to 692.0 3 ± 9.58 mg GAE/100 g (Awika & Duodu, 2017; Sombié, et al., 2018). And it was found to be significantly contributing to the antioxidant

activity. Exposure to heat may affect the availability of this compound. Dehulling and cooking process with boiling water as involved in *tempe* production was found to decrease the total phenolic compound significantly as well as flavonoids in cowpea such as daidzein, myricetin, genistein, and quercetin. Despite the decrease of the total phenolic compound, the health-promoting effect still remained (Barros, Rocha, Glória, Araújo, & Moreira-Araújo, 2017)

Antioxidant activity as well as total phenolic content of cowpea were found to be 59.67% and 1.58% respectively (Table 6). Referring to Dewi, (2010) there is an increase in both compound as fermentation time increased. During the first 30 h of mold fermentation, total phenolic content of cowpea was reported to be the lowest compared to soybean. However, at 42 h of fermentation, total phenolic content of cowpea was increased and higher compared to soybean. Similar finding by

Martins, Petropoulos, & Ferreira, (2016), found that natural lactic acid fermentation in cowpea was reported to give an increase for its ability to inhibit lipid oxidation as well as an increase in total phenolic compound and vitamin E. Another compound contributing to antioxidant activity such as ferulic acid, p-coumaric, tyrosol, and vanillic was also increased significantly due to fermentation process. Another similar finding by Yadav, et al., (2018) reported that a 16 h of natural lactic acid fermentation process applied to cowpea seeds enhance the antioxidant activity of cowpea cultivars. The total phenolic content was reported to increase at 16- 24 hours while total flavonoid content of cowpea was significantly reduced after 6 h of soaking. This is due to the fact that the flavonoids in cowpea seeds are mainly contained in the seed coat and are water soluble.

Table 6. Functional properties of bioactive compound and nutrients of each non-soy *tempe*

Non-soy tempe	Functional Properties	Amount	Method	Notes
Mung bean	Antioxidant activity	86.091% [1]	DPPH radical scavenging activity	Upscaled production
		28.19 mg dry[2] base/ml		IC50
		15.284 mg dry[3] base/ml		
	total phenolic	250.70 mg GAE/g[1] dry base	Folin-Ciocalteu	Upscaled production
		404.89 mg[3] GAE/100g dry base		
		397.92 mg[3] GAE/100g dry base		
	Beta- carotene	15.31 mg/100g [2]dry base	HPLC	
	Amino acid	104.20 mg protein/ 100 g dry base [2]	Lowry	
Cowpea	Antioxidant	59.67% [4]	DPPH	
	total phenolic	1.58% [4]	Folin Ciocalteu	
Jack bean	Antioxidant	3.59% [5]	DPPH	Plastic
		2.53% [5]		Banana leaves
	Resistant Starch	10.27% [6]	AOAC	Fermentation with *L. casei* & *Bifidobacterium*
Red Kidney	Amino acid	37.19 g/100 g [7]	HPLC	
	Soluble protein	51.92 g/ 100 g [7]	Bradford	
	Isoflavone	104.08 mg/ 100 g [8]	AOAC	

Source: (Grace, 2017)[1] (Belinda, 2015)[2] (Angelina, 2016)[3] (Dewi, 2014)[4] (Ardinati, et al., 2018)[5] (Nur'afiah, 2014)[6] (Karisma, 2014)[7] (Maryam, 2016)[8]

Jack bean

Consumption of jack bean has been associated to the health promoting effect. Functional properties such as ferric reducing power, radical scavenging activity of superoxide and DPPH inhibiting power of jack bean showed a higher amount compared to other legumes (Swaffar, Ang, Desai, & Rosenthal, 1994). Raw seeds of jack bean have been known to have a total free phenolic content of 12.98 g catechin equivalent/ 100 g and showed a positive correlation towards the antioxidant activity (Vadivel, Cheong, & Biesalski, 2012). Jack bean shows successful inhibition activity against alpha amylase and alpha glucosidase at 77.56% and 75.45% inhibition in vitro respectively (Vadivel, Cheong, & Biesalski, 2012). Cooking, soaking, and the combination of both, however, results in a significant reduction of these compounds. While on the other hand, scavenging activity against superoxide and DPPH free radical was increased after such processing (Vadivel, Cheong, & Biesalski, 2012).

Fermentation by lactic acid bacteria was also reported to give an impact on jack bean. It was found that fermentation in jack bean was able to produce glucose and resistant starch (Nur'afiah, 2014). One beneficial aspect of resistant starch is to reduce some diseases related to digestion systems like colon cancer since it can act as prebiotic which is able activate microflora in the gut (Nur'afiah, 2014).

Modification of packaging for jack bean *tempe* influenced the antioxidant activity. The antioxidant activity for jack bean *tempe* wrapped in plastic packaging was higher significantly and lipid was lower compared to the one which used banana leaves (Ardinati, et al., 2018). This is supported by the finding from Kurniawan, Setiani, & Dwiloka, (2019) that explained that plastic packaging could produce *tempe* with higher antioxidant activity compared to banana leaves and other kind of leaves since plastics has ability to minimize oxygen exchange around the environment. Another functionality of jack bean *tempe* was investigated. Additionally, jack bean may provide a bioactive peptide with high ACE inhibitory activity when fully fermented into *tempe* (Pupitojati, Indrati, Cahyanto, & Marsono, 2019).

Red kidney

The consumption of red kidney beans, any other legumes and plant-based food has been associated with combating diseases like cancer, obesity, and diabetes. It was reported that phenolic compounds contained in red kidney beans provide anticancer properties (Duranti, 2006; Scalbert, Manach, Morand, Remesy, & Jimenez, 2005). These phytochemicals could be improved by fermentation. A study by Magana, et al., (2019) reported that phenolic content and antioxidant activity may be improved with solid state bioconversion. Similar findings were reported by Limón, et al., (2015), solid fermentation of red kidney beans by *Bacillus subtilis* causes a high phenolic content of 31- 36 mg/g and a high antioxidant activity of 508- 541 µg trolox equivalents/g. On the other hand, liquid fermentation by *Lactobacillus plantarum* was observed to cause high amounts of gamma-aminobutyric acid and angiotensin converting enzyme which are potentially able to be antihypertensive.

Fermentation process involved in *tempe* production gives an impact to red kidney (Limón et al., 2015). As shown in Table 7, red kidney *tempe* contains isoflavones such as genistein, daidzein, glycytein, and factor-2 (Maryam, 2016). Fermentation by molds was found to improve the total isoflavones in red kidney. This is because fermentation facilitate the release of aglycones of isoflavones from its sugar, resulting in higher amount of isoflavones.

Antinutrient

Antinutrients are compounds which have detrimental effect on the consumption of the soybeans. Generally, antinutrients naturally present in any type of legumes. Some of them are beneficial and some may act as an antinutrient. Phytic acid, tannins, antitrypsin, derivatives of carbohydrates and lectin are examples of antinutrients that may not give contribution to the functionality of legumes (Dixit, Jix, Sharma, & Tiwari, 2011). It may interfere the availability of nutrients and minerals by showing behaviors such as inhibition of enzymes activity as well as formation of complex with nutrients resulting in the unavailability of nutrients and minerals.

According to Ogun, Markakis, & Suwanto (1989), cowpea seeds contain about 16.5- 32.0 TIU/mg antitrypsin. This factor is relatively heat resistant which makes it difficult to be removed (Utomo & Antarlina, 1998). Cowpea seeds also contain oligosaccharide and they are mostly raffinose, stachyose, and galactose. These could disturb the digestion system and lead to flatulence (Utomo & Antarlina, 1998). Mung bean contains only a few amounts of sulphur containing amino acid and that makes mung bean only contain a small amount of digestible protein (Kataria, Chauchan, & Punia, 1989). Red kidney bean contains 1.82% of dry weight phytic acid and tannins which is mainly contained in the hulls (Astawan, 2009). Jack bean contains some different antinutrients that is interesting to be examined. Cyanogen, canavanine and concanavalin A are major antinutrients that can be seen as a highlight in jack bean. Concanavalin A can be naturally found in jack bean and represents 20% of total protein in seeds (Dalkin & Bowles, 1983) and its presence of canavanine may inhibit the growth of chickens. As shown in Table 7-9, several processes are able to significantly reduce some antinutrients contained in each legume.

In soybean roasting gives a better and more effective performance in removing antinutrients than compared to cooking. Tannin was found to be the highest among the other antinutrients and roasting seemed to be significantly reduced tannin better than cooking. Further process, which is fermentation, the data shows that fermentation give the best reduction of all antinutrient factors compare to both cooking and roasting. This is due to the presence of α-galactosidase enzyme produced by lactic acid bacteria which can hydrolyze the antinutrient factors (Adeyomo & Onilude, 2013).

Table 7 Antinutrients of milled soybean through some processing

Type of treatment	Antinutrients (mg/ g)			
	Antitrypsin	Tannin	Protease inhibitor	Phytic acid
Raw	1.20 ± 0.12	1.93 ± 0.19	1.20 ± 0.02	1.16 ± 0.05
Cooked	0.05 ± 0.05	1.12 ± 0.02	0.05 ± 0.05	0.28 ± 0.02
Roasted	0.02 ± 0.25	0.49 ± 0.12	0.03 ± 0.03	0.25 ± 0.03
Fermentation (Isolated LAB)	0.010 ± 0.02	0.120±0.05	0.020 ± 0.03	0.047 ± 0.03

Some processing like fermentation, soaking, dehulling, and boiling are possible to reduce the phytic acid concentration and are effective in removing tannins (Astawan, 2009). The effect of processing through some antinutrients in cowpea is shown in Table 9.

Phytic acid in cowpea seeds was found to not be affected by any kind of treatments while for red kidney bean as it can be seen on Table 10 the phytic acid content was reduced to 19% after being soaked for 12 h. This is also similar to phytic acid contained in mung bean which was reduced to 30% after being soaked for 18 h. Additionally, soaking treatment with CaCl2 for 72 hours was investigated to be efficient to remove hydrogen cyanide content in jack bean (Kusumawardhani, 2015). For other antinutrients in cowpea such as antitrypsin, the concentration was found to be massively decreased by cooking process and steaming (Ogun, Markakis, & Suwanto, 1989) (Emire & Rakshit, 2007). For oligosaccharides, both stachyose and raffinose were significantly decreased by almost all treatments except for cold soaking. Tannins were not detected after being dehulled and steamed. This is because most tannins in cowpea are contained in the hulls and are sensitive to heat (Utomo & Antarlina, 1998).

Result showed that soaking and cooking process of red kidney beans does not sufficiently remove the amount of the shown antinutrients, but only lowers it by between on average 26% for phytic acid and on average 52% for α-galactoside. Sprouting is removing a bigger amount of antinutrients with 74-88% which shows that these biological processes are being more effective than just soaking and cooking it. In addition to that germination for 48 h followed by autoclaving is successfully removing phytic acid and tannin. However, the processes were not 100% effective to reduce α-galactosides (Shimelis & Rakshit, 2007). On the other hand, similar treatment such as germination could reduce the content of hydrogen cyanide in jack bean (Akpapunam & Sefa-Dedeh, 1997). Raw form of red kidney beans is also known to contain hemagglutinin which is toxic and able to agglutinate red blood cells. These antinutrients could be removed with the help of heat treatments to the beans at a temperature of 100^0C for a few minutes (Astawan, 2009). Similar with some antinutrients contained in jack bean that urease contained in jack bean was also reported to be easily removed by introduction to heat processing to the seeds.

Table 8. Antinutrient of cowpea through some processing

Treatments	Antinutrients				
	Phytic Acid (% dry wt)	**Tannins (% dry wt)**	**Antitrypsin (TIU/mg)**	**Stachyose (% dry wt)**	**Raffinose (%dry wt)**
Raw	1.2 ± 0.2	0.10 ± 0.05	27.6 ± 8.2	3.1 ± 0.4	1.4 ± 0.5
Dehulled	1.2 ± 0.2	ND	26.6 ± 7.8	2.5 ± 0.3	1.1 ± 0.5
Cold-soaked	1.1 ± 0.2	0.07 ± 0.02	25.7± 7.2	2.7 ± 0.2	1.2 ± 0.5
Hot-soaked	1.1 ± 0.2	0.08 ± 0.03	10.7 ± 3.3	2.6 ± 0.3	1.1 ± 0.5
Cooked	1.0 ± 0.2	0.06 ± 0.02	2.5 ± 0.8	2.0 ± 0.1	1.0 ± 0.5
Steamed	1.0 ± 0.1	ND	2.4 ± 0.6	1.0 ± 0.1	0.9 ± 0.5

ND: Not Detected
Source: (Ogun, Markakis, & Suwanto, 1989)

Table 9. Antinutrients reduction of different cultivars of red kidney bean when processed into tempe

Cultivars	Treatment	Antinutrients reduction (%)		
		Phytic acid	**Tannin**	**α-galactoside**
Type 1	Soaking, 12 h	17	23	45
	Sprouting, 48 h	79	75	88
	Cooking	28	35	53
	Germination 48 h + autoclaving	100	100	93
Type 2	Soaking, 12 h	18	25	41
	Sprouting, 48 h	87	74	80
	Cooking	25	34	49
	Germination 48 h + autoclaving	100	100	91
Type 3	Soaking, 12 h	19	24	45
	Sprouting, 48 h	87	80	88
	Cooking	26	27	53
	Germination 48 h + autoclaving	100	100	93

Source: (Emire & Rakshit, 2007)

CONCLUSION

The use of soybean as raw ingredient for *tempe* production other than non-soy legumes is inevitable. On the other hand, locally produced non-soy legumes in Indonesia such as mung bean, cowpea, jack bean, and red kidney bean have shown greater potential. Utilization of these non-soy legumes as raw ingredient for *tempe* production could be the answer to improve the value of them and thus, the dependency of soybean as ingredient for *tempe* production could be minimalized.

There have been many researches related to the utilization of non-soy legumes as raw ingredient for *tempe*. Further processing into *tempe* showed that nutrient content of each non-soy legumes was improved and compared to soybean *tempe* even shows greater functionalities.

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