Quality nutrition, metal content, and health risks in soy milk products using aluminum and stainless steel cookers

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Uji kualitas nutrisi, kandungan logam dan bahaya bagi kesehatan pada produk susu kedelai dengan bejana pemasak alumunium dan stainless steel

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Abstract

Improper processing of soymilk, such as soybean raw materials, use of well water, and use of cooking vessels, produces soymilk that does not meet SNI standards. These conditions can contaminate soymilk with harmful metals. The purpose of this study was to measure the nutritional quality and metal content of soymilk produced using aluminum and stainless steel cooking vessels. The research was descriptive and was conducted in July 2022. Analytical tests were carried out by comparing the nutritional content in the form of total protein, fat, lactose, and solid non-fat (SNF), and analyzing the heavy metal content. The results showed that the contents of Pb, Cu, and Hg in soy milk processed with stainless steel were lower than those of aluminum, from 11,494 ppm to 2,706 ppm, 114,612 ppm to 10,211 ppm, and 0,372 ppm to 0,012 ppm, respectively. The contents of Zn and As in soymilk with stainless steel were higher than those treated with aluminum, from 884,585 ppm to 73,616 ppm and from 0,107 ppm to 0,079 ppm, respectively. Cooking water also contributed 0,055; 0,044; 0,028, and 0,156 ppm to the heavy metal content of Pb, Cu, Zn, Hg, and As, respectively. In conclusion, the use of stainless steel in soymilk processing resulted in better nutritional quality and lower heavy metal content compared to aluminum.
Keywords: Heavy metals, proximate, soy milk

Abstrak

Pengolahan susu kedelai yang tidak tepat seperti bahan baku kedelai, pemakaian air sumur serta penggunaan bejana pemasak menghasilkan susu kedelai tidak sesuai standar SNI. Kondisi tersebut dapat mengkontaminasi susu kedelai dari logam-logam berbahaya. Tujuan penelitian untuk mengukur kualitas nutrisi dan kandungan logam pada susu kedelai yang diproduksi dengan bejana pemasak dari bahan aluminium dan stainless steel. Metode penelitian adalah deskriptif, yang dilakukan pada bulan Juli 2022. Uji analisis dilakukan dengan membandingkan kandungan nutrisi berupa protein total, lemak, laktosa, dan Solid Non Fat (SNF) dan analisis kandungan logam berat. Hasil, kandungan Pb, Cu dan Hg pada susu kedelai yang diolah dengan stainless steel lebih rendah dari pada alumunium berturut-turut dari 11,494 ppm menjadi 2,706 ppm; 114,612 menjadi 10,211 ppm; 0,372 ppm menjadi 0,012 ppm. Kandungan Zn dan As pada susu kedelai dengan stainless steel lebih tinggi dari pada yang diolah dengan alumunium berturut-turut dari 884,585 ppm menjadi 73,616 ppm serta dari 0,107 ppm menjadi 0,079 ppm. Air pemasak juga berkontribusi terhadap kandungan logam berat Pb, Cu, Zn, Hg, As berturut-turut 0,055 ppm; 0,044 ppm; 0,028 ppm; 0,156 ppm. Kesimpulan, penggunaan stainless steel dalam pengolahan susu kedelai menghasilkan kualitas nutrisi lebih baik dan kandungan logam berat yang lebih rendah dibandingkan aluminium.
Kata Kunci: Logam berat, proksimat, susu kedelai

Introduction

Soybeans are food crops that are widely processed into the form of new products such as tempeh, tofu, soy sauce, and soy milk. East Java Province is recorded to have the highest production of soybean plant products, with a magnitude of 350.000 tons compared to the amount of soybean plant products in Indonesia, which reaches 700.000–800.000 tons each year. Soybean production reaches 42% (Dewi & Wiguna, 2017). Based on these conditions, the creativity of the people of East Java emerged to innovate by processing soybeans into soy milk. The results of the soy extraction process will produce one of the products, namely soy milk. In the production of soy milk, there are several stages of the manufacturing process: being soaked with water, peeled, washed, crushed, then diluted, filtered, and cooked at the end of the process (Olivea, 2021).

Among Indonesian people, there are some people who have allergies if they consume milk with animal protein content. Because of that problem, allegedly soy milk has the potential to replace the role of cow's milk because the amino acid content is not much different. There is a high nutritional content in soy milk, especially in its protein content. Soy milk also contains carbohydrates, fat, phosphorus, calcium, iron, B-complex vitamins, and water. Improper processing of soy milk, namely boiling soybeans with aluminum pans, will actually contaminate soy milk with harmful metals from aluminum erosion, such as lead (Pb), copper (Cu), chromium (Cr), arsenic (US), zinc (Zn), and mercury (Hg). Improper processing of soybeans because the raw materials of both soybeans and water contain high levels of heavy metals and types of aluminum cooking materials will cause soy milk to contain heavy metals beyond the threshold (Muradi & Sugiarto, 2021; Wusono et al., 2023).

Consumption of soy milk with a metal content exceeding the threshold continuously for a long time will be harmful to health (Irianti et al., 2017). Therefore, to prevent heavy metal contamination in soy milk, it is necessary to find safe alternative ingredients, namely materials that do not decompose metals in food ingredients in the storage and processing process.

In addition to aluminum, steel metal, or stainless steel, is also widely used in society and industry. Stainless steel material is used in food or beverage production processes because it is resistant to abrasion and corrosion, has reliable strength, and is resistant to chemical reactions that may arise during the production process. (Priyotomo, 2020).

The main problems in this research activity are related to (a) how the nutritional quality of soy milk cooked with aluminum and stainless steel cooks and (b) how the heavy metal content of soy milk cooked with aluminum and stainless steel cooks. This can be a reference after the replacement of the cooker with different ingredients so that later the product that is the result of the process can be safer for consumption.

Heavy metals are produced from the water used, water for hot steam in steamers, and raw materials. So that it can be recommended to manufacturers to produce soy milk products that are safe, healthy, whole and halal (Aman, Sehat, Utuh, Halal/ASUH). It is very important to provide information to consumers regarding the heavy metal content in soy milk.

The purpose of this study is to compare the metal content of soy milk treated with aluminum material against soy milk treated with stainless steel, measure the heavy metal content in steamer water compared to refill water and well water, and analyze the potential hazards of heavy metal contamination for health. So that the right ingredients can be recommended to process soy milk, so that soy milk sold in the market is completely safe for consumption.

Methods

Experimental research uses a descriptive approach, namely by describing the nutritional value and heavy metal content of soy milk, which is processed using aluminum and stainless steel cooking vessels. The research sample was soy milk produced by PT Sehat Sejahtera Bersama (PT SSB), Sumbersari District, Jember Regency.

The research has been conducted at the Academic Implementation Unit (Unit Pelaksana Akademik/UPA) in Bioscience at Jember State Polytechnic on July 26, 2022. The purpose of the research is to test the quality of nutrients such as total protein, fat, lactose, and solid non-fat (SNF) and metal content such as copper (Cu), lead (Pb), arsenic (US), chromium (Cr), zinc (Zn), and mercury (Hg) in soy milk produced with cooking vessels made of aluminum and stainless steel.

The data collection procedure is carried out through proximate analysis. The proximate analysis method is one of the chemical analyses with the aim of identifying the nutritional content of samples (foodstuffs) such as carbohydrates, fats, proteins, and fiber (Fitriana, 2019). In addition, proximate analysis also produces data on the metal content of foodstuffs. The identifiable metal content is: lead (Pb), copper (Cu), zinc (Zn), mercury (Hg), and arsenic (AS).

There are two samples of soy milk used, namely soy milk obtained with aluminum cooking vessels and stainless steel cooking vessels. Samples taken from soy milk production on the same day came from PT Sehat Sejahtera Bersama (PT SSB), Sumbersari District, Jember Regency. The research was conducted on an industrial scale, with a production capacity of 140 kg of ingredients and 2000 liters of soy milk. The sample used represents 0,5% of the production, or from 2000 liters taken to 10 liters. This research was conducted at UPA Biosain Jember State Polytechnic with ethical approval obtained from the Jember State Polytechnic Health Research Ethics Commission Institute Number: 8187/PL17/PG/2022.

Result and Discussion

Every food processing industry requires equipment to process foodstuffs. The equipment used was both manual and machine-operated (Pranatha, 2020). The soy milk industry uses aluminum pans to boil soybeans. After sampling soy milk processed with an aluminum pan, proximate analysis was carried out with the following results:

Table 1. Proximate analysis of soy milk processed with aluminum and stainless pans

Parameters	Unit	Aluminum Pan	Stainless steel pan	Method Specifications on Aluminum pans	Method Specifications on Stainless Steell Pans
Total protein	%	2,59	2,34	Kjeldahl (SNI 01-2891-1992)	LactoStar © 2008 Funke Gerber
Fat	%	0,19	0,47	Gravimetri (SNI 01-2891-1992)	
Lactose	%	3,8	4,16	SNI 01-2891-1992	
Solid Non Fat (SNF)	%	7,15	7,72	SNI 01.3743.1995	
Lead (Pb)	ppm	11,494	2,706	Atomic Absorption	Atomic Absorption
Copper (Cu)	ppm	114,612	10,211	Cook Book.	Cook Book.
Zinc (Zn)	ppm	73,616	884,585	SHIMADZU	SHIMADZU
Mercury (Hg)	ppm	0,372	0,012	Corporation	Corporation
Arsenic (As)	ppm	0,079	0,107		
pH		6,943	6,71	SNI 06-6989.11-2004	SNI 06-6989.11-2004

The comparison of metal levels in soy milk processed with aluminum-based pans to stainless steel-based pans is as follows (Table 2). Based on this analysis, it is known that there is a heavy metal content in soy milk processed with aluminum pans and soy milk processed with stainless steel. Heavy metals include copper (Cu), arsenic (As), lead (Pb), and mercury (Hg). Lead content (Pb) in soy milk processed with an aluminum pan is 11,494 ppm. The maximum limit of heavy metal contamination, especially lead in the category of drinking products, is 0,05 mg/kg (calculated based on products that are ready for consumption) (BPOM RI, 2021) or 0,05 ppm, so that the lead contained in soy milk exceeds the threshold of BPOM number 7 of 2018. Soy milk treated with a stainless steel-based pan has a lead content of 2,706 ppm, or lower than the waste content treated with aluminum pans. However, the lead level is still higher than the threshold of BPOM number 7 of 2018.

Table 2. Comparison of metal content in soy milk treated with an aluminum pan to a stainless steel pan

Parameters	Unit	Aluminum Pan	Stainless steel pan
Total protein	%	2,590	2,340
Fat	%	0,190	0,47
Lactose	%	3,800	4,16
Solid Non-Fat (SNF)	%	7,15	7,720
Lead (Pb)	ppm	11,494	2,706
Copper (Cu)	ppm	114,612	10,211
Zinc (Zn)	ppm	73,616	884,585
Mercury (Hg)	ppm	0,372	0,012
Arsenic (As)	ppm	0,079	0,107
pH		6,943	6,710

Lead (Pb), which has an atomic number of 82, a weight value of 207,21, and a valence of 2-4, The content of this metal (lead) is not recommended for consumption if it is present in food because of its properties that can cause poisoning, especially in children. Lead properties have no smell and no color. Lead can react with other compounds and then become other lead compounds, such as lead chloride ($PbCl_2$), lead oxide (PbO), and so on (SNI 7387:2009). Lead content can have an effect on health; namely, lead is toxic and can disrupt the system in the human body. The more consumption of foods that contain lead, the more toxins that will settle in the body. Lead can cause long-term effects, especially on the hematopoietic system, kidneys, and nervous system (Kahar & Rappe, 2020). The impact of the presence of lead on children is to cause lead poisoning if it is at very high levels. Examples of symptoms if there is lead poisoning that arises in children are: being easily tired due to anemia; nervous disorders (central nervous system); and encephalopathy (abnormalities in brain function or structure due to a disease (Salsabilla, 2020).

The copper (Cu) content in soy milk processed with an aluminum-based pot is 114,612 ppm; besides, soy milk cooked with a pot made from stainless steel drops to 10% only, which is 10,211 ppm. So even though it is processed with stainless steel, soy milk still contains copper (Cu). Heavy metal use, such as copper, if consumed either through drinks or food, can cause brain damage, decrease kidney function, and settle on the cornea of the eye (Asrillah et al., 2017). The minimum value of copper content in the blood, according to sources from the WHO, is 800-1200 UN (Aribowo et al., 2022) or 0,8–1,2 ppm. While soy milk processed with aluminum pans and stainless steel pans is far above the threshold allowed by the WHO, which reaches 114,612 ppm for soy milk processed with aluminum pans and 10,211 ppm for soy milk processed with stainless steel pans, it is very dangerous and needs other alternative tools to boil soybeans.

Zinc (Zn) is an essential metal needed by humans in small amounts of <100 mg/day, which plays a role in the body's metabolism (Mulyaningsih, 2013). The zinc (Zn) content in soy milk processed with an aluminum pan is 73,616 ppm, while the zinc (Zn) content in soy milk processed with a stainless steel pan is 884,585 ppm. Processing soy milk with stainless steel is proven to increase zinc levels in soy milk. The fullness of Zn minerals can maintain optimal body health. Zn can function as a cofactor for various types of enzymes, cell integrity and structure, DNA synthesis, hormone storage and secretion, immune transmission, and its large role in the immune system. Lack of Zn levels in the body can cause decreased appetite, dermatitis, slow growth, slow sexual maturity, infertility, and immunodeficiency (Widhyari, 2012). Excess Zn content in the human body (with levels greater than 100 mg/day) can have negative effects on toxicity, such as decreased immune system, anemia, a lack of copper (Cu) content in the body, and a lack of HDL (high-density lipoprotein) cholesterol levels in the blood (Mulyaningsih, 2013). The zinc (Zn) content in soy milk processed with stainless steel is 884,585 ppm, or 0,885 mg, which is needed by the body and is still in the safe category.

The nonessential heavy metal mercury (Hg) actually does not have any function in the human body but is very dangerous and can cause poisoning (toxic) in humans (Agustina T., 2014). Soy milk treated with an aluminum-based pot contains 0,372 ppm mercury (Hg). While soy milk processed in a pot made from stainless steel contains 0,012 ppm (0,012 mg/kg), this has decreased significantly. But it still contains mercury (Hg), which is harmful to health. The mercury (Hg) threshold in beverages is 0,005 mg/kg (calculated for ready-to-consume products) (BPOM RI., 2021). So even though the soybean boiling process uses a stainless steel-based pot, it still contains mercury (Hg) in amounts that exceed the threshold determined by BPOM number 5 of 2018. Exposure to mercury in low concentrations over a relatively long period of time can have effects such as tremors, a metallic feeling in the mouth, and difficulty moving the toes or hands (Annisa, 2020).

This type of inorganic arsenic (As) has soluble properties when in contact with water, or it can also be in gaseous form, so that it can cause human exposure. Arsenic is one element that has high toxic properties and can be found in soil, water, and air. Arsenic is very well known as a killer poison because of its highly toxic nature (Agustina, 2014). Arsenic contamination in foodstuffs usually comes from pesticides (Hanum et al., 2019). The arsenic content (As) in soy milk processed with an aluminum pot is 0,079 ppm, while in soy milk processed with a stainless steel pan, the arsenic level actually increases by 0,107 ppm. The maximum limit of arsenic (As) levels in the beverage category according to BPOM number 5 of 2018 is 0,05 mg/kg (calculated against the products consumed), or 0,05 ppm. So that soy milk boiled with stainless steel still contains arsenic (As) in excess amounts. This is very dangerous because arsenic (As) is an element that has been identified as a cause of cancer in humans, and intoxication in the human body against arsenic can cause negative effects on the skin, eyes, and liver (Munandar, 2017).

The results of the analysis of steamer water compared to refill water and well water obtained the following results (Table 3).

Table 3. The results of metal content analysis in stem water, refill water, and well water

Parameters	Unit	Test Results			Method Specifications
		Air steamer	Refillable water	Well Water	
Total Dissolved Solids (TDS)	Mg/L	16	8	16	Gravimetri
Total Suspended (TSS)	Mg/L	28	1	2	
Lead (Pb)	Mg/L	0,055	0,013	0,0116	Atomic Absorption
Copper (Cu)	Mg/L	0,044	0,028	nd	Cook Book SHIMADZU
Zinc (Zn)	Mg/L	0,028	0,033	0,017	Corporation
Mercury (Hg)	Mg/L	nd	0,002	nd	
Arsenic (As)	Mg/L	0,156	0,178	0,377	

The results of the analysis of steamer water compared to refill water and well water obtained the following results: Content tests on stem water, refill water, and well water are needed as additional reinforcement related to the results of the soy milk content analysis test, in addition to the influence of the cooking ingredients used. Lead content (Pb) in steamer water is 0,055 mg/L. This is higher than the metal content in refill water and well water. Lead content (Pb) in soy milk processed with an aluminum pan is 11,494 ppm. Lead content treated with stainless-steel amounted to 2,706 ppm. While the maximum limit of heavy metal contamination, especially lead in the category of drinking products, is 0,05 mg/kg (calculated based on products that are ready for consumption) (BPOM RI., 2021), it can be concluded that the lead content in soy milk comes from contamination of steamer water and aluminum pans.

The copper (Cu) content in steamer water is also higher than in refill water and well water. The threshold value of copper (Cu) allowed by WHO is 0,8–1,2 ppm. So, there is very little copper on the metal stem that decays. The copper (Cu) content in soy milk processed with an aluminum pan is 114,612 ppm, while the copper (Cu) content in soy milk processed with stainless steel is 10,211 ppm. This means that the content of copper (Cu) in soy milk is higher than the contamination of tools used for cooking, most of which are aluminum-based pans, and the use of stainless steel also contaminates soy milk with copper (Cu) above the threshold allowed by the WHO.

No mercury (Hg) was found in the steamer. Mercury is actually found in refill water. This means that the mercury content in soy milk does not come from the metal in the water heating channel. The content of mercury (Hg) in soy milk cooked in an aluminum pot is 0,372 ppm, while in soy milk processed with stainless steel, it is 0,012 ppm. The threshold of mercury (Hg) in beverages is 0,005 mg/kg (calculated on ready-to-consume products) (BPOM RI., 2021). Mercury content comes from contamination of materials for processing milk, which are mostly aluminum and then stainless steel. Soil contamination by mercury can also contaminate soybeans, which are the basic ingredient of soy milk (Lembah et al., 2014).

The metal content of arsenic (As) in well water is higher than in stem water and refill water. However, the arsenic content in steamer water and refill water of 0,156 ppm and 0,178 ppm, respectively, exceeds the maximum limit of arsenic (As) levels in the beverage category according to BPOM number 5 of 2018, which is 0,05 mg/kg (calculated against the products consumed) or 0,05 ppm. Arsenic content in soy milk can come from water used to boil soybeans or from tools used for boiling, namely aluminum or stainless steel.

Conclusion

Soy milk processed with a cooking pan made of stainless steel has a heavier metal content, such as Pb, Cu, and Hg, lower than soy milk processed with an aluminum pan. The content of Zn and As in soy milk processed with stainless steel is higher than that processed with aluminum. From the test results of the metal content in soy milk, it can be said that a cooking pan made of stainless steel can suppress the heavy metal content that is harmful to the body compared to a cooking pot made of aluminum.

Advice related to this research is that the production of safe soy milk and hygiene should use cooking utensils made of stainless steel that are resistant to acid and base (food grade). As a follow-up study found, it is better to use organic soy milk, which is low in heavy metal content.

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