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Characteristics of Tofu Wastewater From Different Soybeans and Wastewater at Each Stage of Tofu Production

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ABSTRACT

Tofu wastewater is a liquid by-product of the tofu production process that typically contains high levels of organic matter, such as proteins, carbohydrates, and fats, as well as other compounds, such as nitrogen, phosphorus, potassium, and COD. Tofu wastewater COD levels can vary depending on the type of soybeans used in the production process and the stages of the production process. This study aimed to analyze the characteristics of tofu wastewater from various types of soybeans and the characteristics of wastewater at each stage of the production process. The research methods used were field research and laboratory tests. Field research was conducted by collecting samples from different types of soybeans and analyzing them in the laboratory. Meanwhile, laboratory tests were run by analyzing samples for various parameters such as Soybeans Protein, Chemical Oxygen Demand (COD), total suspended solids (TSS), Biochemical Oxygen Demand (BOD), ammonia, and fat oil. The results showed that Wonogiri Soybeans had the highest protein parameter, 19%. As far as the wastewater of seed samples, the Wonogiri Seed sample had the highest parameter results for TSS, COD, ammonia, and BOD, which are 444 mg/L, 4583.33 mg/L; 13.86 mg/L; and 3.481 mg/L, respectively. As for the fat oil parameter, the Red Seed sample achieved the highest result of 6264 mg/L. In the case of the samples from each washing stage, it is known that the washing sample parameter results are lower than the seed samples. The Red 1st Washing sample had the highest TSS, COD, fat oil, and BOD values, amounting to 316 mg/L, 4666.67 mg/L, 356 mg/L, and 2053.71 mg/L, respectively. In comparison, the highest fat oil parameter corresponded to the Wonogiri 1st Washing sample with a value of 11.78 mg/L. The B/C ratio of all samples is > 0.1 and is in the biodegradable zone. Thus, the samples are not only able to be treated through biological processes, but also able to be treated through physical and chemical processes to avoid the length of time for biological decomposition due to the acclimatization process of microorganisms to the samples.

Keywords: tofu wastewater; type of soy; COD; tofu production.

INTRODUCTION

Tofu wastewater characteristics may vary depending on the tofu production process used and the wastewater treatment in the tofu factory. Tofu wastewater characteristics refer to the physical and chemical properties of the wastewater generated during the tofu production process. These characteristics include the concentration of organic compounds, such as chemical oxygen demand (COD), total suspended solids (TSS), and total nitrogen (TN), as well as the pH and temperature of the wastewater. The characteristics of tofu wastewater may vary, depending on the type of soybean used in the production process and the stage of the production process. Errors in determining the right treatment based on waste characteristics have the potential to cause disposed waste to pollute the environment because the polluting parameters fail to be set aside.

The wastewater from tofu production can affect the chemical and physical properties of water that are harmful to living things if not treated before being injected into water bodies (Pagoray et al., 2021). Thus, analyzing wastewater characteristics is necessary to determine the appropriate waste treatment method. Wastewater characteristics are measured based on COD, BOD_5, suspended solids, ammonia, nitrate, and nitrite (Henze et al., 2002). From these parameters, two simple parameters need to be measured to determine the quality of tofu wastewater: COD and BOD_5, because these two are the main parameters in determining organic substances in wastewater (Bitton, 2005; Samudro & Mangkoedihardjo, 2010). Organic compounds with high concentrations can cause unpleasant odors and surface pollution of groundwater and rivers (Faisal M et al., 2015). The ratio of BOD_5 and COD can be used in determining the appropriate method to be applied in tofu wastewater treatment through the division of three zones: the stable zone, the biodegradable zone, and the toxic zone. The BOD/COD ratio used for biological processes is in the biodegradable range, within 0.2–0.5 (Samudro & Mangkoedihardjo, 2010). According to (Eslami et al., 2021), the ability of wastewater to break down pollutants (biodegradability) has a relationship with the BOD/COD ratio. If the ratio is < 0.1, the water has toxic characteristics, while if > 0.1, the water can be degraded through treatment or naturally using microbes (Samudro & Mangkoedihardjo, 2010).

Wastewater treatment cannot be done carelessly. In addition to processing results that do not meet quality standards, effectiveness, and efficiency factors are also considered. Carrying out treatment without analyzing waste characteristics can result in parameters not being set aside properly to pollute the environment. In addition, it is also related to financing and land use factors. After knowing the initial characteristics of tofu waste, the processing mechanism can be further determined. Processing can be done biologically, physically, and chemically with various technical considerations. Biological processes are carried out through anaerobic, aerobic, or a combination of both systems (Zunidra et al., 2022). With anaerobic biological processes, the treatment efficiency is only about 70–80%, so wastewater still contains organic pollutants that are high enough and cause odors that constitute nuisance (Asmara, 2019). In general, there are three methods of tofu waste treatment: biological, chemical, and physical (Yulianto et al., 2020).

This study aimed to analyze the characteristics of tofu wastewater from various types of soybeans and the characteristics of wastewater at each stage of the production process. The practical implication of this paper is to provide valuable insight into the characteristics of tofu wastewater from different types of soybeans. This information can be used to make informed decisions on how best to manage and treat tofu wastewater, as well as identify the potential areas for improvement in the production process. In addition, understanding these characteristics may help researchers to develop more efficient methods to treat or recycle waste streams generated by food processing industries such as those involved with producing tofu products.

METHODS

This research was conducted with an experimental method where it was done to look for the influences on other things under controlled conditions. The experimental method carried out in this study is on a laboratory scale. This research was conducted in the Environmental Engineering Laboratory, Department of Environmental Engineering, Faculty of Engineering, Diponegoro University. The source of tofu wastewater tested came from one of the tofu industries, namely ABAH ABU Tahu Sutra located in Jl. Gayamsari IV No.16, Jl. Majapahit No.Kel, RT.1/RW.12, Gemah, Kec. Pedurungan, Semarang City, Central Java 50191. Samples were taken using 24 2-liter jerrycans, consisting of Wonogiri soybean tofu, Pati soybean tofu, red soybean tofu, and green soybean tofu, each taken using 6 jerrycans.

Each jug was used as a container for seed waste, 1^{st} washing, 2^{nd} washing, 3^{rd} washing, 4^{th} washing, and 5^{th} washing. The activity at 1st washing involved washing soybean raw materials, then soaking in warm water for approximately 6 to 12 hours. This is done until the texture of the soybeans is easily processed. In this soaking process, the soybeans will rise. The activity at 2nd washing involved soaking; soybeans are cleaned by washing many times. The activity at 3rd washing consisted in soybeans that are crushed until smooth, usually using a mill or if little is made, a blender can also be used. Water was added gradually so that the soybeans take the form of porridge. The soybean juice was filtered gradually until the soybean pulp is no longer left. This process is often done so soy water can be made into fine tofu. The activity at 4th washing consisted in cooking soybean pulp at a temperature of 70–80 degrees (usually characterized by small bubbles that appear on cooked soybeans). Then, it was necessary to wait until the hot steam dissipates. The soybean porridge was strained, stirring gently. Then, thorough mixing was conducted with the tofu-making ingredients (tofu or sour stones are enough). This process produced a tofu precipitate (blob). The precipitate was ready to be pressed and produce a liquid. The activity at 5th washing consisted in pressing the tofu dough in the mold so that the water in the dough could be squeezed out so that the water content is completely exhausted.

After the samples were taken, tests were carried out protein content of the soybeans, TSS, COD, BOD, ammonia, and fat oil parameters. TSS test was conducted using the gravimetric method, COD using the spectrophotometric method – closed reflux, BOD by Winkler titration, ammonia by phenate method – spectrophotometry, and fat oil gravimetrically. All sample analysis methods refer to the Standard Methods for examining Water and Wastewater (Rice et al., 2017). The concentration of COD was measured using the closed-reflux method of potassium dichromate. A 2.5 mL sample was mixed with digestive juices and digested at 165°C using a thermoreactor for 120 min using Ag_2SO_4-H_2SO_4 as the catalyst. Then, the solution was measured for absorbance value using a UV-Vis spectrophotometer.

RESULTS AND DISCUSSION

The characteristics of tofu soybeans vary

In this study, the characteristics of tofu from various types of soybeans are shown in Table 1. The characteristics of tofu from various types of soybeans are known for their protein content, because protein levels will affect the wastewater quality. Most tofu waste contains protein (Pradana et al., 2018). Protein is obtained from soybeans containing high protein levels, and tofu waste contains remnants of protein that were not used during production (Purwaningsih, 2007). Protein needs to be set aside, because it includes organic matter that can cause odor and pollution in the water and soil environment (Asril et al., 2019).

The characteristics of soybeans used in the tofu industry are judged based on protein content. Testing of soybean protein levels was carried out at the Center for Health Laboratory and Medical Device Testing of Central Java Province. Testing using SNI method 01.2891.1992 with results shown in Table 1.

The protein values represented in Table 1 show that Wonogiri Soybean tofu samples have the highest protein content, then Green Soybeans, Starch Soybeans, and Red Soybeans, amounting to 0.19%, 0.14%, 0.15%, and 0.12%, respectively. On the basis of these results, the tofu protein content from Wonogiri soybeans is the highest compared to other types of tofu, while the tofu from red soybeans has the lowest level. As for the tofu from soybeans, starch, and green soybeans have almost the same protein content in the 14–15% range.

This value is still lower than other types of soybeans, such as IP new, IP 1-year-old, US, Argentina, and Indonesia, which have protein levels of 30.33–36.49% (Arziyah et al., 2019). However, compared to the protein contained in tofu, the protein values in the four samples are still appropriate. The best protein content ever measured based on the influence of bromelin enzyme from pineapple fruit is 16.6195%; the protein content of tofu is 13.6758%; and Chinese tofu is 16.97% (Andarwulan et al., 2018; Simanjuntak, 2021). Proteins consist of a series of amino acids, which are organic matter (Lopez & Mohiuddin, 2020). Organic matter can include proteins, carbohydrates, lipids, and other substances (Silverberg, 2019; Xiao et al., 2020). High protein can indicate high organic matter

Table 1. The protein value of tofu samples of each variation of soybeans

Sample	Protein	Unit
Wonogiri soybean	0.19	%
Pati soybean	0.14	%
Green soybean	0.15	%
Red soybean	0.12	%

that are not used in production and wasted with liquid waste. The tofu from Wonogiri soybeans with high protein content also has a high organic matter content. This will be analyzed in more depth in the next section.

The characteristics of tofu wastewater from various types of soybeans

Fat and oil content

Tofu wastewater contains high protein and fatty acids, which will produce different hydrolysis products (Tian et al., 2012). Tofu waste, which is high in fat, can harm the environment if not managed properly. Oils and fats on the surface of wastewater can form a layer that prevents oxygen penetration into the water, causing the death of aquatic organisms and damaging aquatic life (Lestari, 2020). The fat and oil content in tofu wastewater based on soybean type is shown in Figure 1a.

Tofu wastewater contains the highest fat and oil of 6,264 mg/L produced from soybean Starch Seed. At the same time, the lowest fat and oil content is produced from red soybeans, with levels of 62 mg/L. The fat and oil content in Green Seed and Wonogiri Seed is 322 mg/L, and 416 mg/L, respectively. Oil and fat parameters are not required in the regional regulation of Central Java Province Number 5 of 2011 related to the quality standards of tofu and tempeh industry waste. However, it still needs to be a concern because of its environmental impact. From the results obtained, the fatty oil content of starch seed samples is much higher than other types of soybeans. This can happen because the production process is not because of the characteristics of the soybeans used. The parameters of fatty oils do not need

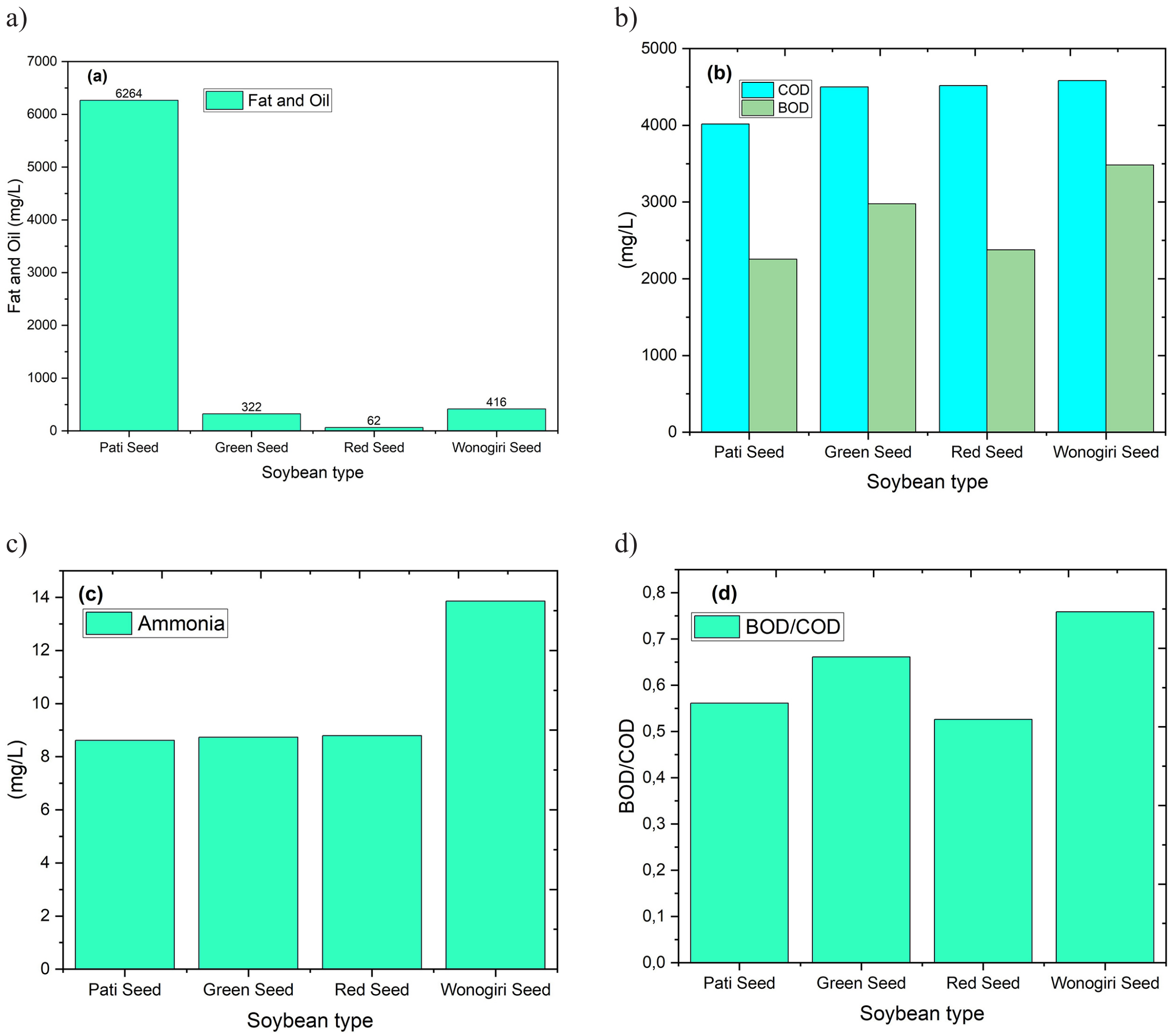

Figure 1. (a) Fat and oil; (b) COD, BOD; (c) Ammonia; (d) BOD/COD ratio in tofu wastewater based on soybean type (starch seed, green seed, red seed, and Wonogiri seed)

special attention, because they can be set aside together with other organic compounds, such as BOD and COD.

Organic contents (COD, BOD, and B/C ratio)

Tofu waste contains a large amount of organic matter. Organic matter can include proteins, carbohydrates, lipids, and other substances (Silverberg, 2019; Xiao et al., 2020). These levels can come from soybean raw materials used in making tofu, as well as unwanted tofu remnants, such as pulp or wastewater from the production process. COD defines the amount of oxygen required to oxidize pollutants through chemical reactions (Wardhana, 1995), the values of which are always greater than BOD, because the pollutants that are reduced through microorganisms in the BOD test are also oxidized in the COD test (Srikandi, 1992). The characteristics of tofu wastewater from various types of soybeans are presented in Table 2.

The four types of soybeans in tofu production showed different results regarding the quality of the wastewater produced. The Wonogiri Seed sample had the highest parameter values for TSS, COD, ammonia, and BOD, amounting to 444 mg/L; 4,583.33 mg/L; 13.86 mg/L; and 3,481 mg/L, respectively. The ratio of BOD and COD (B/C) values of the four samples ranged from 0.526 to 0.759. A B/C ratio of > 0.1 falls into the biodegradable zone where organic compounds can be decomposed naturally by microbes or through treatment (Bitton, 2005; Eslami et al., 2021; Faisal M et al., 2015; Samudro & Mangkoedihardjo, 2010).

From the test results of the four types of samples, although there are variations in the results obtained, there are similar characteristics when emphasizing the BOD and COD parameters as the core parameters. On the basis of previous literature, the BOD values in tofu waste range from 6,000–8,000 mg / L and COD 7,500–14,000 mg / L, which shows that the four samples have relevant BOD and COD values (Faisal Muhammad et al., 2016). However, when compared with the waste quality standards in the Regional Regulation of Central Java Province Number 5 of 2011, the BOD value allowed for the tofu and tempeh industry is 150 mg/L while for COD is 275 mg/L, so the sample is far above the permissible quality standard so that processing is needed before disposal.

Then, by looking back at the B/C ratio, it can be determined the processing that can be done. With these characteristics, it can be determined that the appropriate treatment method to apply is biological treatment due to the high ratio of BOD and COD so that the samples are categorized as easily degradable biologically. However, physical and chemical treatment can be applied because biological treatment takes a longer decomposition time due to the microorganisms needing acclimatization with the waste (Vyrides & Stuckey, 2017).

The parameters contained in the tofu waste can be reduced biologically, including using biofilms with a batch system through the cultivation of *Bacillus sphaerícus* bacteria or with an aerobic-anaerobic biofilm aeration system (Asril et al., 2019; Jaya & Sulistyawati, 2022; Purwaningsih, 2007). Another biological treatment that can be applied is the CSTR (Continuous Stirred Tank Reactor), which uses an air diffuser for transfer (Anshah & Suryawan, 2018). Optimization using Microalgae Microbial Fuel Cells (MMFC) can also reduce COD by up to 31.82% (Hadiyanto et al., 2022). Physical and chemical treatment can also be carried out to remove tofu wastewater parameters, because BOD is part of COD, so reducing COD physically and chemically will also reduce BOD levels. Physical treatment includes ozonation which works through the destruction of microorganisms in water or through aeration and filtration methods as well as adsorption using zeolite or other adsorbents (Karamah et al., 2019; Koch et al., 2002; Simanjuntak, 2021). Thus, the tofu waste from these four types of soybeans can be set aside through biological, chemical, and

Table 2. presents the characteristics of tofu wastewater from various soybeans

No	Sample	TSS (mg/L)	COD (mg/L)	AMMONIA (mg/L)	Fat Oil (mg/L)	BOD (mg/L)	BOD/COD
1	Pati seed	218	4,016.67	8.61	6,264	2,254.74	0.561
2	Green seed	344	4,500	8.73	322	2,976.06	0.661
3	Red seed	392	4,516.67	8.79	62	2,375.63	0.526
4	Wonogiri seed	444	4,583.33	13.86	416	3,481	0.759

physical processes, just adjusted to the needs of their treatment (Lopez & Mohiuddin, 2020).

Ammonia and TSS contents

The ammonia and TSS levels of tofu wastewater from various types of soybeans are presented in Table 3. Ammonia is the result of the breakdown of nitrogen in organic form by putrefactive bacteria obtained through the decay of plants or animals (Sulistia & Septisya, 2019). Total suspended solids (TSS) are among the primary pollutants that cause water quality degradation, increased costs in water treatment, decreased fish resources, and water aesthetics (Verma et al., 2013).

From Table 3, it is known that the highest ammonia content corresponds to Wonogiri seed samples with a value of 13.86 mg/L, while the smallest ammonia content is exhibited by Starch seed samples with a value of 8.61 mg/L. This value is quite linear with TSS levels which both show that Wonogiri seed samples have the largest TSS value and Starch seed samples have the smallest TSS levels, amounting to 444 mg/L and 218 mg/L, respectively. In the tests conducted by previous researchers in Kuranji District, Padang City, the value of ammonia in tofu waste was 10.2 mg/L. This value is still relevant to the values of the four tofu samples. Meanwhile, related to TSS, based on the tests conducted in previous research on industries in Semanan, West Jakarta, Indonesia, the TSS levels of tofu waste ranged from 442–840 mg/L (Raivaldi et al., 2021). Another study revealed that the TSS value of tofu waste can reach 740 mg/L. Therefore, in both ammonia and TSS values, the four tofu waste samples in the study have results that are quite relevant to previous studies.

The characteristics of wastewater at each stage of the tofu production process

Fat and oil contents

In the washing sample consisting of 5 stages, the highest oil and fat content was exhibited by the red soybean sample produced in washing stage 1 with a concentration of 356 mg/L. Meanwhile, the lowest fat and oil content corresponded to the Wonogiri sample produced in washing stage 3

Table 3. presents the characteristics of tofu wastewater at each stage of the production process

No	Sample	TSS (mg/L)	COD (mg/L)	Ammonia (mg/L)	Fat oil (mg/L)	BOD (mg/L)	B/C
1	Pati 1st washing	216	1350	8.29	308	680.43	0.50402
2	Pati 2nd washing	24	104.63	0.34	140	57.14	0.54611
3	Pati 3rd washing	12	92	1.66	222	35.86	0.38978
4	Pati 4th washing	36	104.63	1.02	84	34.07	0.32562
5	Pati 5th washing	12	59.368	0.7	50	20.59	0.34682
6	Green 1st washing	104	3100	1.24	20	1793.52	0.57855
7	Green 2nd washing	16	43.05	1.74	342	30.57	0.7101
8	Green 3rd washing	8	100.42	0.48	12	36.19	0.36039
9	Green 4th washing	20	102	0.84	44	35.77	0.35069
10	Green 5th washing	68	100.95	0.52	12	37.34	0.36989
11	Red 1st washing	316	4666.67	4.21	356	2053.71	0.44008
12	Red 2nd washing	108	61.47	10.66	152	41.85	0.68082
13	Red 3rd washing	36	103.58	0.9	18	45.6	0.44024
14	Red 4th washing	44	104.63	1.32	16	45.95	0.43917
15	Red 5th washing	16	105.16	0.8	12	50.62	0.48136
16	Wonogiri 1st washing	100	3266.67	11.78	30	2073.8	0.63484
17	Wonogiri 2nd washing	196	102	5.53	10	59.4	0.58235
18	Wonogiri 3nd washing	108	68.84	2.56	4	31.71	0.46063
19	Wonogiri 4th washing	32	78.32	3.64	10	35.93	0.45876
20	Wonogiri 5th washing	12	65.16	3.14	6	40.7	0.62462

with a concentration of 4 mg/L. Table 3 shows the parameter values of the tofu waste at each washing stage. There are five washing stages for four types of tofu from different soybeans. From the results obtained, it is known that the parameter values of the washing samples are lower than the seed samples. The Red 1st Washing sample has the highest fat oil, as high as 356 mg/L. In comparison, the highest fat oil parameter is exhibited by the Wonogiri 1st washing sample with a value of 11.78 mg/L. In this washing sample, the characteristics of the tofu waste from red soybeans are generally worse than other tofu wastes, compared to the tofu waste from Wonogiri soybeans, the seed samples of which are the worst.

Organic contents (COD, BOD, and B/C ratio)

The organic contents of COD, BOD, and B/C of tofu wastewater at each stage of the tofu production process are shown in Table 3. From the test results, it is known that the highest COD is 4,666.67 mg/L produced by washing stage 1 with red soybean samples. In turn, the lowest COD of 43.05 mg/L produced washing stage 2 with green soybean samples. The highest BOD of 2,073.8 mg/L was produced by washing stage 1 with Wonogiri soybean samples. At the same time, the lowest BOD of 20.5 mg/L was produced by washing stage 5, with the highest soybean Starch / BOD / COD sample of 0.7101 mg/L produced by washing stage 2 with green soybean samples. In contrast, the lowest BOB/COD of 0.32562 produced washing stage 4 with a sample of soybean starch. Table 3 shows the parameter values of the tofu waste at each washing stage. There are five washing stages for four types of tofu from different soybeans. From the results obtained, it is known that the parameter values of the washing samples are lower than the seed samples.

The Red 1st Washing sample has the highest COD, and BOD values, 4,666.67 mg/L, and 2053.71 mg/L, respectively. In this washing sample, the characteristics of the tofu waste from red soybeans are generally worse than other tofu wastes, compared to the tofu waste from Wonogiri soybeans, the seed samples of which are the worst. The B/C ratio of the tofu washing waste sample is also still in the biodegradable zone, so the treatment method that can be applied is still the same as the previous sample.

The levels of COD and BOD are better than the quality of the tofu waste studied by Faisal (Faisal Muhammad et al., 2016), where tofu wastewater has COD levels ranging from 7,500–14,000 mg/L, a BOD of 6,000–8,000 mg/l, and ammonia levels of 23.3–23.5 mg/l. The tofu wastewater from a local tofu industry in Jl. Cipta Karya, Tuah Karya Village, Tampan District, Pekanbaru City, Riau contains COD of 2,466 mg/L (Elystia et al., 2023).

Ammonia and TSS contents

The ammonia and TSS contents of tofu wastewater at each stage of the tofu production process are presented in Table 3. The highest ammonia of 11.78 mg/L was produced by washing stage 1 with Wonogiri soybean samples. Conversely, the lowest ammonia of 0.34 mg/L produced washing stage 2 with Pati soybean samples. The highest TSS of 316 mg/L was produced by washing stage 1 with red soybean samples. In turn, the lowest TSS of 8 mg/L produced washing stage 3 with green soybean samples. This means that Wonogiri soybean samples in washing 1 experience the most decay of organic compounds compared to other samples, while Pati soybean samples for stage 2 washing apply the opposite. The TSS value indicates the number of solids suspended in the wastewater. Red soybean samples at washing stage 1 contain the highest TSS; it is physically shown that many deposits are formed when tofu waste is left for a while. In contrast, green soybean samples for stage 3 washing contain the least solids compared to other samples.

The tofu wastewater from a local tofu industry in Jl. Cipta Karya, Tuah Karya Village, Tampan District, Pekanbaru City, Riau, contains ammonia of 15.56 mg/L (Elystia et al., 2023).

Scoring consumer interest in tofu types

Scoring consumer interest in tofu types is used to estimate if the tofu is produced, knowing which type is the most popular, which means that the chances of the tofu being produced are higher and higher. Questionnaires were filled out by 20 respondents who tried four types of tofu sampled, with the observed parameters of color, taste, aroma, softness, chewiness, and preference. A recapitulation of the questionnaire results can be seen in Table 4. The highest color score is 165 points for red soybean-type tofu, and the lowest score is 155 for green soybean-type tofu. The highest taste score is Starch soybean-type tofu, with 167 points, and the lowest is green soybean-type tofu, with 152 points. For aroma parameters,

Table 4. results of consumer questionnaires on all four types of tofu

Parameters	Total amount of wonogori soybeans	Average	Total amount of pati soybeans	Average	Total amount of red soybeans	Average	Total amount of green soybeans	Average
Color	161	8.05	164	8.2	165	8.25	155	7.75
Taste	159	7.95	167	8.35	162	8.1	152	7.6
Aroma	147	7.35	155	7.75	159	7.95	146	7.3
Softness	165	8.25	163	8.15	167	8.35	154	7.7
Chewiness	159.5	7.975	166	8.3	175	8.75	155.5	7.775
Preference	157	7.85	172.5	8.625	177	8.85	147	7.35

the highest points were obtained by red soybean samples with 159 points, and the lowest was green soybean-type tofu with a score of 146. The highest softness score of 167 was obtained by red soybeans, and the lowest score of 154 was obtained by green soybean-type tofu. The highest chewiness score was obtained by red soybean-type tofu, with 175 points, and the lowest was obtained by green soybean-type tofu, with a score of 155.5. Finally, for the favorability parameter, red soybean tofu also obtained the highest score of 177 and the lowest green soybean tofu with a score of 147.

The questionnaire results showed that the tofu from red soybeans obtained the highest score, especially for the parameters of color, aroma, softness, chewiness, and preference. Meanwhile, for taste parameters, the tofu from Pati soybeans is the most preferred by consumers, which puts the tofu from Starch soybeans in the second position. The third and fourth places are the tofu from Wonogiri soybeans and green soybeans. From these results, it can be concluded that, generally, the highest score is obtained from the red soybean-type tofu, and the lowest is obtained from the green soybean-type tofu based on consumer choice.

Previous research has discussed consumer preferences for tofu. On the basis of the study, it was found that the origin of tofu and soybeans used had a major influence on consumer preferences. The consumers who did not consume meat regularly were found to have a higher willingness to pay for locally produced tofu and organic cultivation (Weigel, 2022). However, in Indonesia, tofu producers more often use imported soybeans because they have cheaper prices (Rasyid, 2021). In addition, Indonesian people who often consume meat make tofu as a source of complementary protein so that the preference for local production and organic cultivation of soybeans has not become a trend that consumers are interested in.

CONCLUSIONS

This study aimed to determine the characteristics of tofu wastewater from various types of soybeans and the characteristics of wastewater at each stage of the tofu production process. The results showed that for various types of soybeans, Wonogiri Soybean tofu samples have the highest protein content, then Green Soybeans, Starch Soybeans, and Red Soybeans. For seedling samples, Wonogiri Seed samples had the highest parameter values for TSS, COD, ammonia, and BOD amounting to 444 mg/L; 4583,33 mg/L; 13,86 mg/L; and 3,481 mg/L, respectively. As for the fat oil parameter, the Red Seed sample achieved the highest value of 6,264 mg/L. As for the samples from each washing stage, it is known that the washing sample parameter values are lower than the seedling samples. The Red 1st Washing sample had the highest TSS, COD, fat oil, and BOD values, equal to 316 mg/L, 4,666.67 mg/L, 356 mg/L, and 2,053.71 mg/L, respectively. In comparison, the highest fat oil parameter was exhibited by the Wonogiri 1st Washing sample with a value of 11.78 mg/L. The B/C ratio of all samples is > 0.1. It is in the biodegradable zone, so the samples can be treated through biological processes. It can also go through physical and chemical processes to avoid the length of biological decomposition due to the acclimatization process of microorganisms to the samples. The practical implication of this paper is that it provides valuable insight into the characteristics of tofu wastewater from different types of soybeans. This information can help make informed decisions on how best to manage and treat tofu wastewater and identify the potential areas for improvement in the production process. In addition, understanding these characteristics may help researchers to develop more efficient methods to treat or recycle waste streams generated by food processing industries, such as those involved with producing tofu products.

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