Comparative study on the physical characteristics of goat milk pasteurization through serial and circulation systems of ultraviolet method

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Abstract. This research was intended to evaluate the physical characteristics of pasteurized goat milk by serial and circulation systems of ultraviolet (UV) rays. The parameters measured covered viscosity, specific heat, conductivity, pH, water content, freezing point and specific gravity. The UV reactor system consisted of a reactor housing made of ST 316 material equipped with 10W UV lamp, UV-C 253.7 nm and a quartz tube with 1.80 J per square cm or 2314.83 J per liter as a dose per reactor for the serial system and 1.56 J per square cm as a dose for circulation system. The results of the serial system showed that the physical characteristics were not significantly different from the control at 0.5 percent, whilst the circulation system with flow rate of 10 cc per second and dose of 1.56 J per square cm showed that the treatment of two, four and six circulations on viscosity treatment had different effect from the control (P less than 0.01), whereas other treatments did not differ from the control (P more than 0.05).

1. Introduction

Fresh milk was defined as liquid produced from clean and healthy goat, obtained by proper milking with its natural content and it was not reduced or added to anything and did not receive any treatments, except the cooling process without affecting its purity [1]. Milk referred to liquid in white emulsion produced by milking the milk that could be drunk and used as food product that was safe for consumption. Goat milk had different characteristics compared to cow milk, in which it had whiter color, its fat was easier to digest, its curd protein was softer which making it possible to make special cheese, containing minerals (potassium, phosphorus, vitamin A, vitamin E and B complex [2].

Pasteurized milk referred to fresh milk, reconstituted milk or recombined milk that had undergone heating process at minimum temperature of 63-66 ^{o}C for 30 minutes or minimum temperature of 72 ^{o}C and was being heated for 15 seconds, then it was immediately cooled to 10oC, then treated aseptically and stored at maximum temperature of 4.4 ^{o}C [3]. The purpose of pasteurization was to kill pathogenic and non-pathogenic bacteria while maintaining the bacterial spores, also extending the shelf life of milk [4]. Pollutant bacteria in milk were divided into two groups, including pathogenic and spoilage bacteria. Both were capable to cause diseases known as milk-borne diseases such as tuberculosis, typhoid fever and brucellosis [5]. The main cause of poisoning was due to its ability to penetrate,

survive and multiply on host cells including *Salmonella sp., Staphylococcus Aureus, Clostridium Perfringens, Bacillus Cereus, Campylobacter sp., Shigella sp., Clostridium Botulinum* and *Escherichia Coli*. The danger level of these bacteria depended on several factors covering the environment (food composition, temperature) and bacterial factors such as strain and type of toxin [6].

The UV application to food products was one of the non-ionizing irradiation techniques. Irradiation was the process of applying energy radiation to food products. UV light had wavelengths between 100 to 400 nm, in which UV-A (315-400 nm) caused skin discoloration to black which was called as "tanning", UV-B (280-315 nm) which caused sunburn and was often used for radiation of cancer, UV-C (200-280 nm) which belonged to germicidal region and effective for inactivation of bacteria and viruses, and UV-vacuum (100-200 nm) which could be absorbed by all materials and continued only on vacuum conditions [7]. The wavelength range was 253-264 nm which had germicidal peak effect known as the germicidal spectrum.

The treatment of UV light was commonly used to inactivate the microorganisms from liquid foodstuffs such as juice, apple vinegar and milk. The application of UV method did not cause organoleptic and nutritional characteristics of food to change [8]. Some advantages of UV disinfection process were low operating cost, environmentally friendly and safe to use. UV method had been generally accepted as one of the disinfection processes, especially in food and water [9].

Food processing by using the thermal method had many negative effects, thus we needed an alternative to replace the conventional processing with non-thermal processing method. One of non-thermal method being developed was by using High Pulsed Electric Field (HPEF). HPEF was defined as the application of high voltage electric pulse fields of 20–80 kV/cm or 10-100 kV/cm^2, in which liquid food was passed between two electrodes through short time [10]. The research on HPEF technology in Indonesia was still very limited, that was why the research on the design of HPEF was required to conduct.

2. Literature review

2.1. Serial system

The estimation of UV dose was calculated by using the radial model [11], i.e.

$$UV\ dose = Intensity\ \left(I_{(r)}\right) \times Treatment\ time\ (T)$$

$$I_{(r)} = \frac{P_L}{2\ \pi\ r} \tag{1}$$

The efficiency of UV-C lamp (quartz or soft glass type) was 25%-35% [12], so the predicted UV-C dose was 33.85 mW/cm2. The time needed to fill the room on UV reactor with flowrate of 4.32 ± 0.71 cc/sec is

$$Treatment\ time\ (T) = \frac{Reactor\ Volume\ (L)}{Flowrate\ (L/hour)} = \frac{0.23\ L}{15.55\ ^L/_{hour}} = 53.24\ second \tag{2}$$

The UV dose per reactor was calculated from the multiplication between Intensity (I) and Treatment time (T), so that it obtained:

$$UV\ dose = Intensity\ \left(I_{(r)}\right) \times Treatment\ time\ (T)$$

$$= 33.85\ \frac{mW}{cm^2}\ x\ 53.24\ s = 1802.15\ \frac{mWs}{cm^2} = 1802.15\ \frac{mJ}{cm^2} \tag{3}$$

The dose of UV-C per volume was calculated based on the division of UV lamp power by flow rate (liters/second), it obtains

$$Dose\ per\ volume\ \ =\ \frac{10\ W}{0.0043\ L/_{hour}}\ =\ 2314.83\ J/L \tag{4}$$

2.2. Circulation system

The circulation system was performed by using Diaphragm of Deng Yuan Brand TYP-2500N pump; 24 VDC; 0.6 A; 80 psi (0.6 LPM) with flow rate of 10 cc/sec which was set by using Dawyer flow meter. The treatment time (T) per reactor was performed as follows:

$$Treatment\ Time\ (T) = \frac{Reactor\ Volume\ (L)}{Flowrate\ (L/jam)} = \frac{0.23\ L}{36\ L/_{hour}} = 23\ second \tag{5}$$

The dose of UV which was given twice on circulation system was calculated from the multiplication between Intensity (I) and Treatment time (T) pointed by Koutchma, thus the results obtained were as follows:

$$UV\ dose = Intensity\ \left(I_{(r)}\right) \times Treatment\ time\ (T)$$

$$= 33.85\ \frac{mW}{cm^2}\ \times\ 46\ s = 1557.06\ \frac{mWs}{cm^2}\ =\ 1557.06\ \frac{mJ}{cm^2} \tag{6}$$
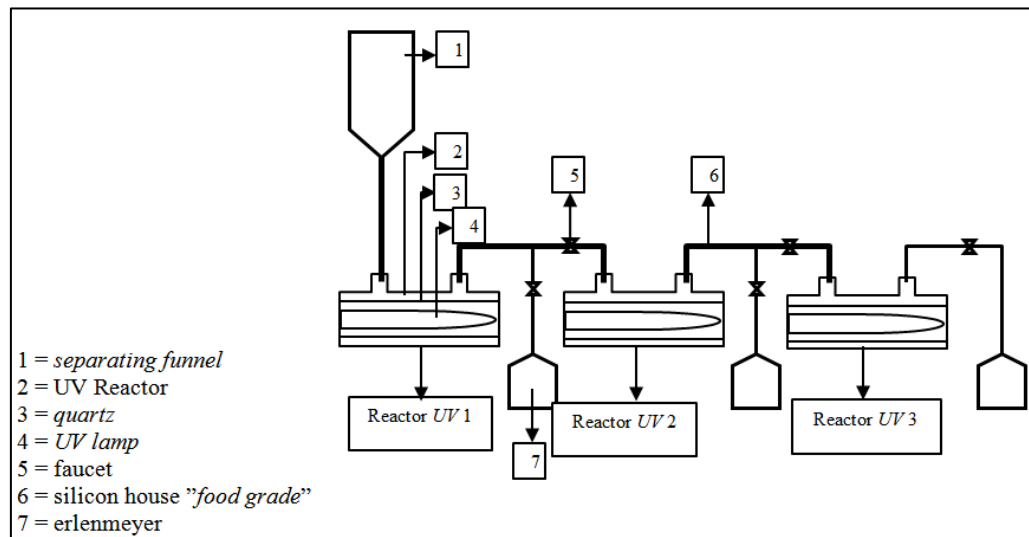
3. Methodology

3.1. Tool and material

The materials used was goat milk obtained from people's farms in Ciampea, Bogor. The tools used was milk vessel, UV-C reactor output of Kadind Brand GPH 180T5L/10W made by Kada (USA) Inc., Deng Yuang brand TENG-2500N Reverse Osmosis pump, faucets, flowmeter, silicone hose "food grade", Faucet, milkotester, pH meter, conductivity meter and falling-ball type viscosimeter.

3.2. UV reactor system

3.2.1 Serial system. The UV reactor system was designed and manufactured by Kada (USA) Inc. consisting of a reactor housing made of ST 316 material equipped with 10W UV lamp, UV-C 253.7 nm and a quartz tube with a dose per reactor of 1.80 J/cm^2 or 2 314.83 J/L. A sample of 1 liter of goat milk was passed to UV-C reactors 1, 2 and 3, while the milk samples were taken as much as 100-200 ml at each UV reactor to be tested for physical characteristics (Figure 1).

Flowrate was measured by using volumetric method, which was by storing milk in an Erlenmeyer container of 100-200 ml and then recorded the time using a stopwatch. The average flow of milk obtained was 4.32 ± 0.71 cc/sec, so the time needed to fully fill the UV reactor with volume of 230 ml was 53.24 seconds. One bacterial cell would receive exposure to 3 UV reactors with 159.72 seconds as exposure time.

1 = *separating funnel*
2 = UV Reactor
3 = *quartz*
4 = *UV lamp*
5 = faucet
6 = silicon house *"food grade"*
7 = erlenmeyer

Figure 1. Serial system.

3.2.2 Circulation system. The UV reactor system was designed and manufactured by Kada (USA) Inc. The reactor consists of intake and discharge channels made of ST 316 material, 10W UV lamp, UV-C 253.7 nm, quartz tube with a dose per circulation of 1.56 J/cm^2. Milk samples as much as 3 liters were pumped from milk tank 1 (temperature 27 ± 1^oC), flowed to the flowmeter (discharge was set at 10 gallons per hour or 10.52 cc/sec) to the UV reactor's inlet, the UV lamp was connected to 220 V AC electric scalar (in position on) until milk flowed into milk tank 2 (tank 1 was washed by using boiling water), which was then pumped to milk tank 1. If all milk had been drained in tank 1, tank 2 was washed by using boiling water. This stage was called as 1 circulation. Milk was taken as much as 1 liter for each treatment of 2, 4 and 6 circulation to be tested for physical, chemical and total microorganism characteristics. The chart of UV pasteurization equipment is shown on Figure 2.
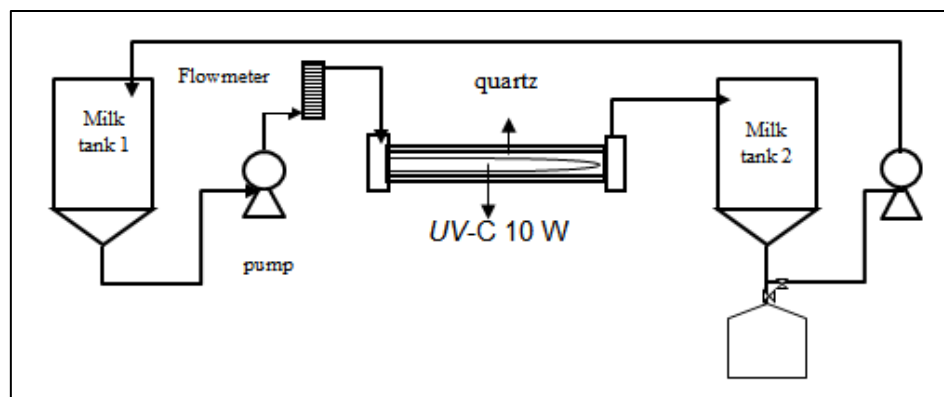
Figure 2. Circulation system.

4. Experiment and results

4.1. Physical characteristics of serial and circulation systems of goat milk after given UV-C treatment
This research was intended to obtain the best conditions of serial and circulation system in the pasteurization process of goat milk on its physical characteristics compared to fresh goat milk

(control). The physical characteristics of goat milk treated with UV-C 253.7 nm are shown on Tables 1 and 2.

Table 1. Physical characteristics of milk goats treated with the serial system of UV-C 253.7.

Testing	Treatment			
	Control*)	Reactor 1	Reactor 2	Reactor 3
Physical Characteristics				
Viscosity	2.08 a ± 0.02	2.34 a ± 0.31	2.29 a ± 0.29	2.03 a ± 0.10
pH	6.52 a ± 0.05	6.54 a ± 0.05	6.55 a ± 0.03	6.58 a ± 0.01
Specific Weight	1.03 a ± 0.00	1.03 a ± 0.00	1.03 a ± 0.00	1.03 a ± 0.00
Conductivity	4.61 a ± 0.15	4.59 a ± 0.14	4.59 a ± 0.14	4.67 a ± 0.07
Freezing Point	-0.49 a ± 0.00	-0.48 a ± 0.00	-0.48 a ± 0.00	-0.48 a ± 0.00
Specific Heat	3.78 a ± 0.01	3.79 a ± 0.01	3.79 a ± 0.01	3.79 a ± 0.01

Table 2. Physical characteristics of milk goats treated with the Circulation system of UV-C 253.7.

Testing	Treatment			
	Control*)	2 Circulation	4 Circulation	6 Circulation
Physical Characteristics				
Viscosity	2.05 a ± 0.00	2.10 b ± 0.01	2.13 c ± 0.01	2.33 d ± 0.02
pH	1.03 a ± 0.00	1.03 a ± 0.00	1.03 a ± 0.00	1.03 a ± 0.00
Specific Weight	4.36 a ± 0.06	4.38 a ± 0.04	4.42 a ± 0.05	4.42 a ± 0.06
Conductivity	6.37 a ± 0.03	6.37 a ± 0.05	6.30 a ± 0.10	6.22 a ± 0.15
Freezing Point	-0.49 a ± 0.01	-0.48 a ± 0.01	-0.48 a ± 0.01	-0.47 a ± 0.01
Specific Heat	3.76 a ± 0.01	3.77 a ± 0.01	3.78 a ± 0.01	3.78 a ± 0.01

Note: Numbers followed by the same letters on the same line showed the values that are not significantly different at the test level < 0.05

*) the milk samples were same and did not get serial and circulation-system of UV treatment

4.2. Viscocity

The milk at under normal condition, its viscosity was influenced by the concentration of fat, protein, temperature, pH and age of milk, whereas the viscosity of goat milk measured at 20 ^{o}C was 2.12 cP [13]. The results of analysis of variance showed that the UV reactors arranged in serial showed no significant difference in viscosity when compared with goat milk as a control, whereas in the circulation system there was a significant difference between the control treatment with two, four and six circulation treatments with viscosity values for series and circulation treatments covering 2.03-2.54 cP and 2.05-2.33 cP.

Viscosity tended to decrease when the temperature of the liquid increases [14]. This condition was different from the results obtained, referring the viscosity of milk tended to increase with increasing milk temperature. The above conditions were explained by the casein granules in goat's milk which

were able to eliminate the effect of increase of temperature. The increased viscosity of milk during the UV exposure process was due to protein coagulation resulting in a higher viscosity.

4.3. pH value

The pH value of goat milk under normal condition was 6.50-6.80. The results of analysis of variance showed that in serial and circulation systems, the controls were not significantly different from the successive treatments that were 6.52-6.58 and 6.22-6.37. The pH value of goat milk in UV system arranged in serial according to the range. Some mineral milk such as: acetate, phosphate and citrate were buffered as these minerals were able to maintain the pH of the milk to be normal, if the acidity of the milk increases due to microorganism activity, the pH change was not apparent, this was due to the buffer characteristics itself

The pH value which tended to increase caused viscosity raising as the result of the breakdown of casein granules. Decreasing the pH of milk in general caused a slight decrease in viscosity, whereas more drastic decrease in pH would cause an increase in viscosity due to casein aggregation. Viscosity of milk was slightly affected by the process of homogenization. Viscosity did not change when the pH decreased in the range of 6.4–5.4 in which case granules approached uniformly in size and distribution; at pH 5.4-5.3 it was reported that maximum viscosity increased and the casein was at the initial stages of aggregation; while in the pH range 5.1-4.6 viscosity tended to decrease.

4.4. Specific weight

The specific weight of goat milk in normal condition was 1.029-1.039 g/cm^3. The results of analysis of variance showed that both serial and the circulation systems, the control was not significantly different from the treatment with the range of values covered 1.0314 -1.0297 g/cm^3 and 1.0298-1.0289 g/cm^3. The value of specific gravity of the measurement results still met the specific requirements of specific types of goat's milk. This lower specific gravity value was thought due to the measurement of specific gravity and it must be done 3 hours after the milk was already milked. Early designation showed smaller BJ results. This was due to the changes in the condition of fat and the gas arising in the milk.

4.5. Conductivity

The conductivity of goat milk according to normal conditions was 4.3-13.9 mS. The results of analysis of variance showed that both the serial and circulation systems were not significantly different between control and treatment with successive values ranging from 4.59-4.67 mS and 4.36-4.42 mS. The increase in conductivity was due to an increase in temperature due to the UV exposure process.

4.6. Freezing point

The freezing point of goat milk under normal condition was -0.540 to -0.573 ^{o}C. The results of the analysis of variance in the serial and circulation systems between control and treatment did not show any significant difference with successive values ranging from -0.488 ^{o}C to -0.479 ^{o}C and -0.49 ^{o}C to -0.47 ^{o}C. The addition of milk with water showed a freezing point that was greater than water and smaller than milk. This was because the boiling point of water was 100 °C and milk was 100.16 °C. The boiling point also changed with the adulteration of milk with water. The freezing point of control with treatment tended to decrease, this indicated that there was no addition of water to goat's milk. Addition of 1% of water, the freezing point of milk increased by 0.0055 ^{o}C, the freezing point lower with the increase in the amount of lactose and dissolved ash. Fat and protein had very little or no effect on the freezing point of milk.

4.7. Specific heat

According to Singh and Heldman [15], specific heat was directly proportional to the value of water content. The higher the water content of a material, the higher the specific heat value. Specific heat values were calculated using the method of Singh and Heldman where: $Cp= 1.675 + 0.025w$. The results of the analysis of variance showed that the control and treatment were not significantly

different both in the serial and circulation systems with a range of values of 3.78 - 3.79 and 3.76 - 3.78 kJ/kg ^{o}C, respectively. The specific heat value tended to increase between 0.01 - 0.02 kJ/kg^{o}C, this was because the water content of goat milk also increased by 0.05%.

5. Conclusions

The treatment of exposure to UV rays of the serial system was not significantly different from the viscosity of goat milk, while the circulation system caused a noticeable difference to the viscosity. The results of analysis of variance showed that the pH, specific weight, freezing point and heat specific of goat milk in the serial and circulation systems, were not significantly different. In general, the physical and chemical characteristics of treated goat milk still met the requirements of Thai Agricultural Standards.

6. References

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