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Embedded water for home industry yogurt: A study for saving potential of water to face climate change

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Abstract. Some studies show that climate change influences the virtual water of products. Meanwhile, the impact of embedded water to life, especially in water aspect, is extraordinary. For the sake of saving water, studies on shadow water should be encouraged. The aim of this study was to calculate the embedded water of home industry yogurt from a producer in Bogor, Indonesia. The study was carried out using observations and in-depth interviews. The result showed that around 24 litres of virtual water in the form of blue water and grey water for cooling and dilution processes were needed to produce one litre of yogurt.

1. Introduction

Clean water is one of the most essential substances for human beings to survive. People are facing a fresh water crisis during the 21st century [1]. Sudan is an example of how a water crisis might trigger conflicts [2]. The possibility of water conflicts in this century is increasing due to climate change. The climate change may affect water resources around the world [3], such as in Angola, Namibia and Botswana [4], Africa [5,6], California [7], Southern Ontario [8], Mississippi and Quebec [9], China [10,11,12], Nepal [13], Pakistan [14], Greece [15], North-East Spain [16], Southern France [17], United Kingdom [18,19,20], and Australia [21].

Climate change gives a deeper and a wider impact to water than just what can be seen. This change influences the virtual water content of crops [22]. The virtual water is economically invisible and politically silent but its impact is immediate [23]. Agricultural water consumption in China, for example, is 64.8 % of the national total water consumption [12]. The impacts of climate change on the virtual water cannot be generalized because they might vary from one product to another product. This is because the virtual water, introduced for the first time by Allan in 1996 [24], is relatively new. Virtual water studies listed by Hoekstra *et al* [25] are still limited for coffee, cotton, flowers, jatropha, mango, maize, meat, onions, paper, pasta, pizza, rice, soft drinks, soybean, sugar, tea, tomatoes, wheat, beer, cola, orange juice, breakfast cereal, candies and pasta sauce. Meanwhile, products or services that embody virtual water keep growing rapidly. Hence, there are so many virtual waters of products such as yoghurt that has not been studied yet.

The purpose of this study was to compute the virtual water of yogurt resulted by a producer in Bogor, Indonesia. This study can be used as the base to save water not only to yogurt producers but for anyone.

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2. Basic Theory

Briefly, the climate is the average weather, but operationally, the climate definition is non-trivial. Werndl [26] showed that there are five desiderata for climate definitions, where one of which mentions that climate as the ensemble distribution of the climate variables when the external conditions vary as in reality.

Embedded water is also called virtual water, embodied water, exogenous water, or shadow water [25]. Embedded water is the total volume of freshwater that is used to produce a particular good or service [27].

There are many kinds of water, such as blue water, grey water, green water, white water, and black water. For virtual water, the water is limited only to the blue water, grey water, and green water. Blue water is the ground and earth surface water, green water is the rain water, and grey water is the freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards [25].

Yogurt is one kind of milk product. Fresh milk as the input is processed by adding impurities in the form of yogurt-forming bacteria, namely *Streptococcus thermophilus* and *Lactobacillus bulgaricus*.

3. Methodology

This study was divided into three phases, i.e. data gathering, data analysis, and information presentation. The data gathering was conducted using three methods, namely observation, in-depth interview, and experiment. The observation was utilized to determine the process to produce yogurt. This observation was completed with an in-depth interview. If needed, a simple experiment was used to obtain the virtual water for yogurt.

The data analysis was utilized to obtain virtual water. One of which was the virtual water for the cooling process. In this process, the hot milk can, after being pasteurized, was placed inside a bathtub that contained the cooling water. Because the milk can was hotter than the water, there was a heat transfer from the milk can to water. The general formulas of physics and chemistry below describe the process.

$$Q_w = Q_m \quad (1)$$

$$m_w \cdot c_w \cdot (T_x - T_w) = (m_c \cdot c_c + m_m \cdot c_m) \cdot (T_{mc} - T_x) \quad (2)$$

where:

Q_w = Heat gained by water (kcal)
Q_m = Heat lost by milk can and milk (kcal)
m_w = mass of water used for the cooling process (kg)
m_c = mass of milk can (kg)
m_m = mass of milk (kg)
c_w = specific heat of water (1 kcal/(kg °C))
c_c = specific heat of milk can refer to aluminium (0.22 kcal/(kg °C))
c_m = specific heat of milk (0.94 kcal/(kg °C))
T_x = temperature of the fermentation process (°C)
T_w = temperature of water used for the cooling process (°C)
T_{mc} = initial temperature of milk and milk can (°C)

Since the mass can be calculated by the multiplication of volume and density, Equation 2 can be rewritten as follows.

$$V_w = \frac{(V_c \cdot \rho_c \cdot c_c + V_m \cdot \rho_m \cdot c_m)}{\rho_w \cdot c_w} \cdot \frac{(T_{mc} - T_x)}{(T_x - T_w)} \quad (3)$$

where:

V_w = volume of water used for the cooling process (m^3)
V_c = volume of milk can (m^3)
V_m = volume of milk (m^3)
ρ_w = density of water (kg/m^3)

ρ_c = density of milk can refer to aluminium (kg/m^3)
ρ_m = density of milk (kg/m^3)

The above equation was used to calculate the volume of water needed to decrease the milk temperature from 80 °C to 45 °C. This cooling water temperature should be reduced again to at least 38 °C, which is the temperature of first-class river water that can be used as the raw water for drinking. Reducing temperature was conducted by adding more water. The additional water can be calculated by the following equation.

$$V_{wa} = \frac{(T_x - T_y)}{(T_y - T_{wa})} \cdot V_w \quad (4)$$

where:
T_y = temperature of first-class water (°C)
T_{wa} = temperature of additional water (°C)

The wasted milk should fulfil the threshold of liquid waste. The milk should be liquefied using fresh water so that the milk parameters were not exceeding their threshold levels. Based on the Regulation of Environment Minister No.5, 2014, the monitored parameters for milk waste are BOD (Biochemical Oxygen Demand), COD (Chemical Oxygen Demand), TSS (Total Suspended Solid), oil and grease, NH3-N, pH, and density (Table 1).

Table 1. The threshold level for liquid waste in milk factory (Regulation of Environment Minister no 5, 2014).

Parameter	Threshold level	Parameter	Threshold level
BOD	40 (mg/l)	NH_3-N	10 (mg/l)
COD	100 (mg/l)	pH	6-9
TSS	50 (mg/l)	Density	1.5 (ton/m^3)
Oil and grease	10 (mg/l)		

Every milk parameter that was higher than the threshold level (Table 1) should be diluted using Equation 5. The solute, in this case, was each parameter such as BOD, while the solvent was water.

$$M_1 V_1 = M_2 V_2 \quad (5)$$

where:
M_1 = the dominant milk parameter value before dilution (mg/l)
V_1 = volume of milk (l)
M_2 = threshold level for milk on Table 1 (mg/l)
V_2 = volume of water for dilution (l)
The dominant milk parameter value before dilution was the value that would give the biggest ratio from the threshold level.

4. Result and Discussion

All processes to produce yogurt could be classified in 12 steps, namely milk testing, milk storage, pasteurization, starter making, starter testing, mixing, cooling, fermentation, taste enhancing, packaging, transportation, and washing/dilution (Figure 1). The arrived fresh cow milk was first tested using alcohol. The sample was then poured into the nearest sewer. If the milk was rejected, it would be brought back to its cattle rancher for calf feedings. In case it was accepted, the milk was stored in a freezer. The milk in a clean milk can was pasteurized at 80 °C to kill the germs. The temperature was then decreased to about 45 °C in 30 minutes. An amount of 20 litres of the milk was then mixed with 1 litre of starter milk. The starter milk is a combination of fresh milk with two types of yogurt-forming bacteria, namely *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. The mixed milk was fermented for around 12 hours to form plain yogurt. The plain yogurt was added with colouring and flavour enhancers, then packed and sent to destination places.

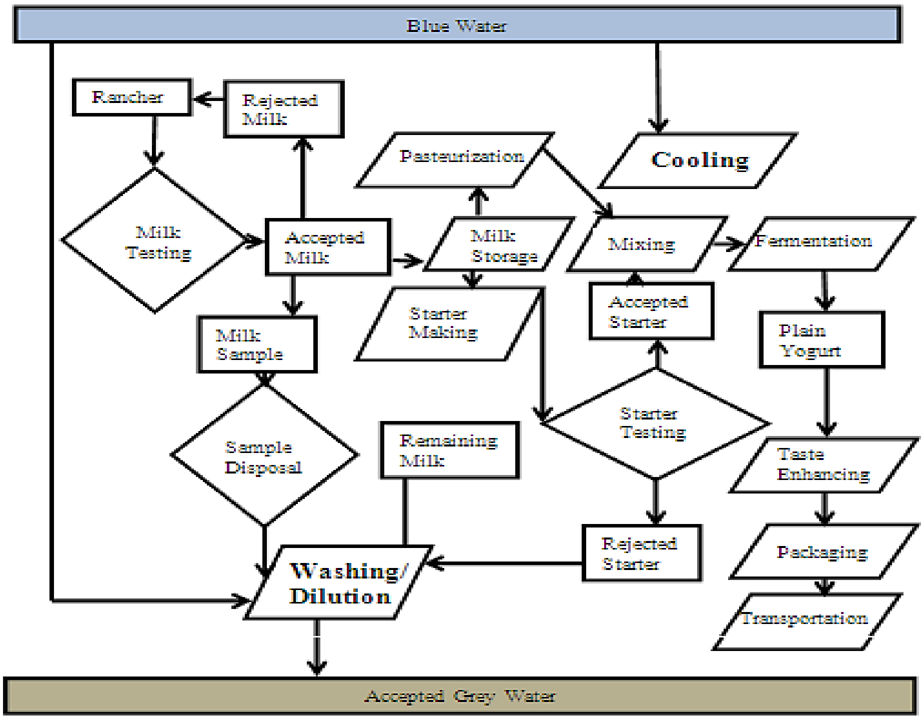

Figure 1. Some processes to produce yogurt.

From Figure 1, there were two processes that need much water, cooling and washing (dilution). The water for cooling will be presented first.

There were two kinds of cooling. The first cooling was used to decrease the temperature from 80 °C to 45 °C while the second one was utilized to reduce the temperature from 45 °C to 38 °C. Applying Equation 3, the minimum water volume for the first cooling was about 35.1 litres. Using Equation 4, the water needed for second cooling is 19 litres. So, for every 20 litres of milk, 54.1 (35.1 + 19) litres of water was needed for cooling. In brief, the cooling process needed 2.705 litres of water for every litre of milk.

The potential liquid waste from yogurt production was the milk from sample disposal, rejected starter and remaining milk. This kind of liquid was discarded to the nearest sewer. The disposal, however, should fulfil the Regulation of Environment Minister No.5, 2014 (Table 1). Based on laboratory analysis, the majority of prerequisites parameters surpassed their threshold levels (Table 2).

Table 2. A laboratory analysis of milk parameters.

Parameter	Test result	Threshold level	Dilution	Assumption of waste 1 %
BOD	5810.1 (mg/l)	40 (mg/l)	145.3	1.453
COD	212281.2 (mg/l)	100 (mg/l)	2122.8	**21.228**
TSS	39650.0 (mg/l)	50 (mg/l)	793	7.930
Oil and grease	8926.0 (mg/l)	10 (mg/l)	892.6	8.926
NH_3-N	2.633 (mg/l)	10 (mg/l)	0.3	2.633
pH	4.69	6-9		
Density	1.019 (g/l)	1.5 (ton/m^3)		

To comply with the regulation, the milk should be diluted first. According to Equation 5, the dilution needed was 2122.8 l to make all parameters of milk waste followed the requirement. The milk waste, however, was only around one per cent of the yogurt product. Thus, the dilution required was 21.228 litres for every litre of yogurt.

Table 3. Embedded water components for one litre of yogurt.

Process	**Embedded water for l litre of yogurt (l)**
Cooling	2.705
Washing	21.228
Total	23.933
Rounded	24

Table 3 shows that at least 24 litres of freshwater were embedded to produce 1 litre of yogurt. This ratio would increase if the water use was inefficient. This problem becomes more significant due to climate change that impacts water resources.

To reduce the embedded water and participate in the water saving, the producer should take at least some realistic actions below.

- For the cooling process, water can be reused by soaking milk cans filled with milk in a bathtub. The water height in the bathtub should be adjusted equal to the height of the milk in its milk can.
- Water temperature can be decreased by ambient air to the permitted temperature (38 °C) or below before it is flushed to the sewer or public water body.
- For the dilution process, wasted or diluted milk can be used for cattle consumption before it is stale or expired to consume.

5. Conclusion and suggestion

The embedded water for one litre home-industry yogurt was 24 litres. The virtual water was used especially for cooling and dilution processes. Yogurt products used the blue water source and gave impact in the form of grey water to the sewer.

Due to climate change, water in the future is getting scarce. Hence, water saving is compulsory. To participate in the water saving program, yogurt producers should reuse the water by immersing milk cans with their milk in a bathtub. The water surface in the bathtub should be adjusted equal to the height of the milk in its milk can to make a homogenous temperature decrement. The water temperature in the bathtub is reduced by the air in the room before discharged to the sewer. Furthermore, for the dilution process, the wasted or diluted milk should be consumed for cattle before it is stale or expired.

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