

COMPARISONS BETWEEN MEASUREMENT AND CALCULATION METHODS IN OBTAINING VIRTUAL WATER FOR HOME MADE YOGURT

PERBANDINGAN ANTARA METODE PENGUKURAN DAN METODE PERHITUNGAN DALAM MENDAPATKAN AIR MAYA UNTUK YOGURT INDUSTRI RUMAH TANGGA

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ABSTRACT

The aim of this study was to get shadow water result comparisons for home industry yogurt using practical (direct measurement) and theoretical (calculation) methods. For every liter of yogurt, the embodied water obtained from the empirical technique was 20.2 liters, namely 3.8 liters lower than the mathematical technique. The differences of the embedded water between two methods were caused especially on one side the producer did not optimize the water potential to absorb the heat, and on the other side the producer did not pay any attention to the regulation in disposing the waste water that should not be higher than its threshold level. The consumption of exogenous water could be decreased if the cooling water was recycled, water heat was dissipated using natural air, and the unused milk was consumed by cattle.

Keywords: virtual water, measurement method, calculation method, yogurt

ABSTRAK

Tujuan dari penelitian ini adalah untuk mendapatkan perbandingan hasil air maya untuk yogurt industri rumah tangga menggunakan metode pengukuran dan metode perhitungan. Untuk setiap liter yogurt, air maya yang diperoleh dari metode pengukuran adalah 20,2 liter, yaitu 3,8 liter lebih rendah dari metode perhitungan. Perbedaan air maya antara dua metode tersebut disebabkan terutama di satu sisi pembuat yogurt tidak mengoptimalkan potensi air untuk menyerap panas, dan di sisi lainnya produsen tersebut tidak memperhatikan peraturan dalam membuang air limbah yang seharusnya tidak lebih tinggi dari ambang batasnya. Konsumsi air maya dapat dikurangi jika air pendingin didaur ulang, panas air dilesapkan menggunakan udara alami, dan susu yang tidak digunakan dikonsumsi oleh ternak.

Kata Kunci: air maya, metode pengukuran, metode perhitungan, yogurt

1. INTRODUCTION

Although virtual water looks like an abstract phrase, its impact is real. Water traded as virtual water constitutes a significant portion of global water consumption (Orlowsky et al., 2014). At the University of Virginia in 2014, the indirect water usage was almost 9 (15.2/1.7) times the use of direct water (Natyzak et al., 2017). The virtual water balance in Alto Tiete WRMU (Water Resources Management Unit), Sao Paulo, Brazil, for example, shows that this area is very much deficit, because its virtual water import ($2558.2 + 98.0 + 11.5 = 2,667.7$ hm³, cubic hectometer) is very much higher than its virtual water export ($635.1 + 149.6 + 17.3 = 702.0$ hm³) (Ussami & Guilhoto, 2018). Virtual water import related to agriculture products in European Union river basins increases with increasing population density (Vanham, 2013). Virtual water affects the use of water everywhere, for example virtual water may increase water stress in the exporting countries (WWAP, 2009a). The virtual water flow in global commodities is 1,625 billion cubic meters a year or about 40% of total world water consumption, where around 80% and the remainder of this flow relate to agricultural products

trade and industrial products trade respectively (WWAP, 2009a; WWAP, 2009b).

Based on the above reasons, virtual water researches need to be encouraged. Virtual water studies have helped to raise the awareness of water scarcity and its impact on food security and to improve the understanding of the role of food trade in compensating for water deficit (Yang & Zehnder, 2007). Turning to business and trade, further research on virtual water and water footprints would have an important influence on international trade policy (Winpenny, 2009). Between one-third and a half of the world's population do not enjoy an acceptable standard of water and sanitation (WWAP, 2009c). Briefly, researches in virtual water are expected to give alternative ways to solve water problems, so that every creature that needs fresh water can enjoy water as it should. Water problems are caused by many factors such as the global energy trade where crude oil trade is the main actor in the whole energy-water nexus (Duan & Chen, 2016), and even by food-energy-water nexus (Salmoral & Yan, 2018).

So far, virtual water study results usually were presented as absolute values.

The virtual water of yogurt, for example, is 24 liters water for every liter of yogurt (Wijonarko et al., 2019). Virtual water export for coffee from Latin America and the Caribbean between 1996 – 2005 was 39 billion m³/year (Mekonnen et al., 2015). The results on the above information are not directly accompanied with their techniques to obtain the virtual water. Meanwhile, the virtual water study results actually also depend on their methodologies. Hence in order to improve methodology explicitness in virtual water results, the epistemologies should be attached to the results.

The purpose of this study was to gain the embedded water of yogurt utilizing empirical and conceptual techniques. Then, the comparisons of both procedures could be used to attain their strengths and weaknesses.

2. BASIC THEORY

The synonym of virtual water is embedded water, embodied water, exogenous water, or shadow water (Hoekstra & Chapagain, 2008 in Hoekstra et al., 2011). Virtual water as opposed to real water (Hoekstra, 2008) is goods and services with a substantial water content either in the finished product or in its production (WWAP, 2009b) particularly in the form of imported agricultural commodities (WWAP, 2009a); or total water volume

used for consumption and trade (Satriyo et al., 2017).

The virtual water for meat is much larger than vegetarian food (Hassing et al., 2009). The meat come from faunas (consumers) while the vegetarian food come from floras (producers). Hence, the process to produce meat is more numerous than the process to produce vegetarian food.

The cost of virtual water embodied is its opportunity cost or its value in the best alternative use (Winpenny, 2009). It depends on water availability. When this water is scarce, or there are potential alternative uses for it, this opportunity cost is significant; but if water is ample, and there are no feasible alternative uses for it, its opportunity cost can be zero, or close to it. (Winpenny, 2009).

Virtual water studies are very important. Virtual water in traded commodities is important for water sustainability management (Tian et al., 2018). Virtual water flow provides a new solution for resolving regional water shortage and improving water use efficiency in the world (Sun et al., 2016). Virtual study can help to establish policies for optimizing the use of water resources and improving water security especially in countries facing water scarcity risks such as Tunisia (Souissi et al., 2017).

Some theories have been developed to compute virtual water of products and services. A method to assess water footprint (Hoekstra et al., 2011) is one of which. Whatever the computation method, it should be directed to make water saving, not water loss. A water saving/loss is the surplus (deficit) difference in water productivity between importing and exporting regions from an inter-regional perspective (Zhao et al., 2018).

Measurement has something to do with assigning numbers that correspond to or represent or preserve certain observed relations (Roberts, 1985). Measurement is different from calculation on their scale type. According to Roberts (1985), the scale of calculation is absolute, while the scale of measurement can be ratio (such as temperature on the Kelvin scale), interval (such as temperature on the centigrade or Fahrenheit scale), ordinal (such as intelligence tests), or nominal (such as curricular codes).

Yogurt (yoghurt) is the food produced by culturing one or more of the optional dairy ingredients (cream, milk, partially skimmed milk, or skim milk, used alone or in combination) with a characterizing bacterial culture that contains the lactic acid-producing bacteria, *Lactobacillus bulgaricus* and *Streptococcus thermophiles* (USFDA, 2018). The bacteria are used to

affect the aroma and flavor of yogurt (Chen et al., 2017). The total sugar, fat, protein, calcium and energy contents were highly variable across categories, and the ranges were extremely broad (Moore, Horti, & Fielding, 2018). The discovery of yogurt was obtained between 10,000 – 5,000 BC, when Herdsmen began the practice of milking their animals, and then they stored their milk in bags made of the intestinal gut of the animals (Mulyawan, 2017). It has been consumed for thousands of years by different civilizations (Rul, 2017). Yogurt is very beneficial to the consumer health - such as for elderly (El-Abadi, Dao, & Meydani, 2014) - for certain gastrointestinal conditions, including lactose intolerance, constipation, diarrheal diseases, colon cancer, inflammatory bowel disease, *Helicobacter pylori* infection, and allergies (Adolfsson, Meydani, & Russell, 2014). It provides a nutrition-dense food, a rich of calcium, essential amino acids, a significant amount of probiotic bacteria, lactose tolerance increment, an immune enhancement and prevention of gastrointestinal disorders (Weerathilake et al, 2014).

3. METHOD

Formulas on this calculation method (theoretical method, or mathematical technique) for yogurt has been presented

by Wijonarko et. al (2019). These formulas are redisplayed in more gorgeous display for the clarity of the next discussion.

The first formula (Figure 1) is based on the Black Principle, namely by mixing the two substances, the amount of heat that is released substances higher temperature

$$Q_w = Q_{mc} \tag{1}$$

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

where:

Q_w = Heat gained by water (kcal)

Q_{mc} = Heat lost by milk can and milk (kcal)

m_w = mass of water use for 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 made from aluminum (0.22 kcal/(kg °C))

equal to the number of heat received by a lower temperature substance. The more detail formula is depicted on Equation 2. Both formulas are applied for the cooling water to absorb the heat from the milk and milk can.

c_m = specific heat of milk (0.94 kcal/(kg °C))

T_x = temperature of fermentation process (°C)

T_w = temperature of water use for cooling process (°C)

T_{mc} = initial temperature of milk and milk can (°C)

Equation (2) can be transformed to Equation (3) and Equation (4) .

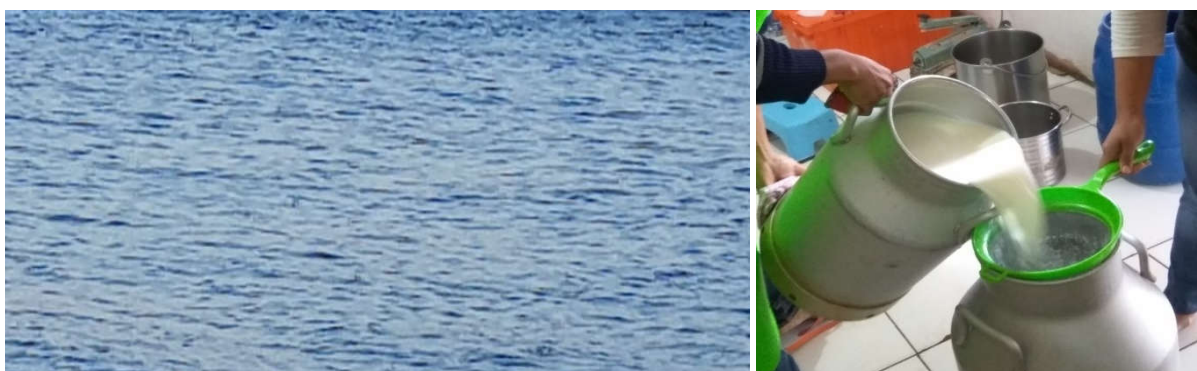


Figure 1. Heat transfer depiction from hotter material (milk and milk can to cooler material (water)

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

where:

V_w = volume of water used for cooling process (m^3) & ρ_w = density of water (kg/m^3)

V_c = volume of milk can (m^3) & ρ_c = density of milk can made from aluminum (kg/m^3)

V_m = volume of milk (m^3) & ρ_m = density of milk (kg/m^3)

Equation 3 (the first stage cooling process) is the formula to attain water volume for cooling down the heat of milk and milk can.

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

where:

T_y = temperature of first class water ($^{\circ}C$)

T_{wa} = temperature of additional water

Equation 4 (the second stage cooling process) is the formula to count water volume used to decrease the temperature of water, so the disposed water can comply the standard for wasted water. The formula for milk dilution follows general formula for dilution. Disposed milk is poured with water to form diluted milk until it meets the regulation requirement.



Figure 2. Volume of water for cooling process.



Figure 3. The disposed milk is added with water to satisfy wasted milk standard

$$M_1V_1 = M_2V_2 \quad (5)$$

where

M_1 = the dominant milk parameter value before dilution (mg/l)

V_1 = volume of disposed milk (l)

M_2 = threshold level of liquid waste for milk (mg/l)

V_2 = volume of water for dilution (l)

M_1 is the parameter that yield the most amount water for dilution; while M_2 value is based on the Regulation of Environment Minister no 5, 2014 (Figure 4). Virtual water from the dilution process is based on the dominant parameter. The other parameters must have met the requirements.



- BOD \leq 40 mg/l
- COD \leq 100 mg/l
- TSS \leq 50 mg/l
- Oil and grease \leq 10 mg/l
- NH₃-N \leq 10 mg/l
- pH 6-9
- Density \leq 1.5 ton/m³

Figure 4. Liquid waste threshold levels in milk factory based on Regulation of Environment Minister no 5, 2014 (Kambuaya, 2014)

Practical method (practical method, measurement method, mensuration method, or empirical technique) is based

on the process to make yogurt. The process is obtained from observations at

field and in-depth interviews to the producer and workers.

The process is observed starting from the input process and ending at the output process. The input is the activity to test milk from cattle ranchers that come to the yogurt producer. The ending process is the product marketing.

The in-depth interview is used to get detail data. Furthermore, this activity is also used to verify the data obtained from the observations.

The obtained process, then, was classified in two groups. The first group comprises processes that need water, while the second one contains processes that do not need water.

Water used in the first group was measured using a water meter (Figure 5). The instrument - made of plastic - has input or output pipe diameter 1/2 inch, flow capacity 1.5 m³/h, and resolution 0.0001 m³.

The water meter was connected to the water faucet used to flow water for the cooling and washing processes. The connection was not direct, but through a connector pipe. The connector pipe should be flexible enough, both to the water faucet and to the flow meter, to make the installation easier.

The water volume measurement was conducted after there was no water leakage in all above connections.



Figure 5. The instrument to measure virtual water

The measurement operators recorded the value printed on the water meter at the time before and after production. Then,

they measured the amount of yogurt products.

4. RESULTS AND DISCUSSION

From the calculation, the virtual water for every liter of home industry yogurt was rounded 24 liters (Wijonarko et al., 2019). The embedded water was used for cooling process 2.71 liters and dilution (washing) process 21.23 liters. Other processes such as milk testing, milk storage, pasteurization, starter making, starter testing, mixing, fermentation, taste enhancing, packaging, and transportation had no significant contribution for that exogenous water (Enclosure).

From the measurement, the shadow water for one liter of home industry yogurt was 20.2 liters. 20 liters and 0, 2 liters were used for cooling and washing respectively. It is assumed that the milk content constant. Actually, wide variations in chemical composition (Richmond, Chandan, & Stine, 1979) such as fat, protein, total solids, and caloric contents (Kroger & Weaver, 1973) or milk components were observed (Sommerfeldt & Baer, 1986).

Specific and general results of both methods were difference. Although it used much more water for cooling, the actual method used much less water for washing. Hence, the gamut water consumption or the virtual water using measurement method was lower than utilizing calculation method for some reasons.

First, the yogurt producer spent much water for cooling. 2.71 liters was sufficient, but they utilized 20 liters or more than seven times higher than what was needed. They spent so much water because they flushed down directly the milk can and other equipment. Therefore, the cooling water could not absorb the temperature optimally. Second, the yogurt producer consumed very little water for washing. The washing in the actual process was intended to clean the equipment, not to dilute the waste especially the milk.

Table 1. Measurement and calculation method comparison of virtual water for home industry yogurt

Process	Virtual water (l)		General Remarks on the Measurement Method
	Mensuration	Calculation	
Cooling	20	2.71	Inefficient water cooling
Washing	0.2	21.23	Pay no attention on regulation
Total (rounded up)	20.2	24	

This action could not fulfill the Regulation of Environment Minister no 5, 2014 concerning the threshold level for liquid waste in milk factory.

Sophisticated technology has not arrived yet to the home made yogurt productions. Hence, the process here is so different with the process in modern yogurt industries.

It is important to save water, but attention to the regulation should also be paid. For this sake, Wijonarko et al (2019) give suggestions especially to the yogurt producers. First, they should reutilize the cooling water by changing the flushed away technique with dying technique using a bathtub where the water surface in it as height as the milk surface to give a homogenous temperature decrement. The water temperature in the bathtub is decreased by the air in the room, before entering to the sewer. Second, use the wasted or diluted milk for cattle consumption before the milk is damaged.

5. CONCLUSION

Based on this case, practical and theoretical methods have their strengths and weaknesses that in some detail aspects are not apple to apple to compare as presented on the Table 1. Hence these methods give very sharp different result especially in the component levels. They

should be used together, so that they can complement each other.

ACKNOWLEDGMENT

The authors would like to express sincere gratitude to all concerned parties who gave assistance for this research and publication, especially to Indonesian Institute for Sciences and Ministry of Research, Technology and Higher Education of the Republic of Indonesia for this research funding in 2018.

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